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NA-TP-03-01

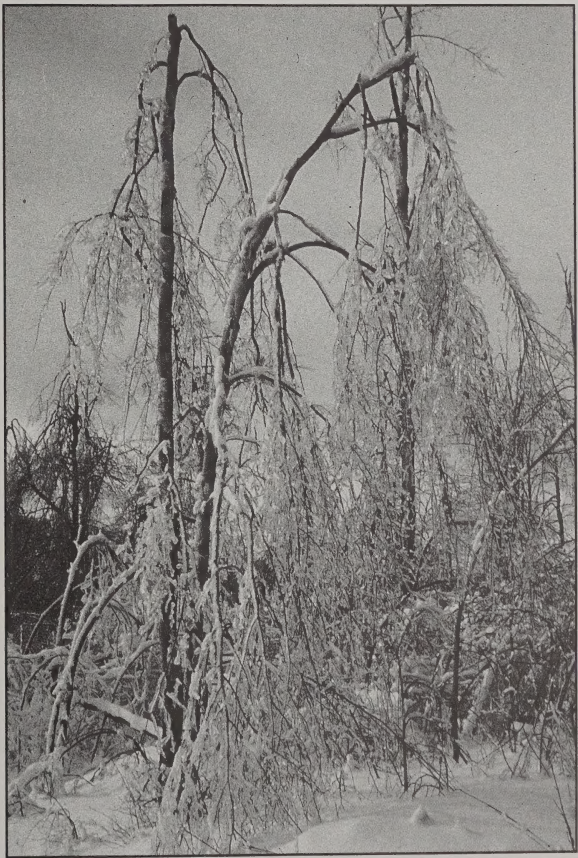
April 2001

Proceedings

New York Society of American Foresters
Ice Storm Symposium

January 29, 1999

Cortland, New York



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Ice Storm Symposium

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Cortland, New York

Compiled by:
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State University of New York
College of Environmental Science and Forestry
Syracuse, New York

Symposium presented by:

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Preface

Immediately following the ice storm of January 1998, a broad range of Federal, state, and provincial agencies responded to forest owners' inquiries about what to do, what to expect, and, in general, how to respond to this event. Published accounts of smaller scale ice storms in many of the affected areas during the past century provided partial answers to these questions. It was soon evident, however, that the combined magnitude of the geographic area affected and level of ice deposition in 1998 was very unusual. Also, it was evident that many agencies were involved in damage surveys, landowner assistance programs, and initiation of diverse research projects.

The Forest Science and Technology Committee of the New York Society of American Foresters thought it would be beneficial to bring together the key players from all jurisdictions and agencies to share concerns, discuss views on appropriate forest management responses, and review approaches used to document damage. Even though it will take several years to complete research projects and fully assess the short- and long-term consequences of varying levels of ice damage in different forest types and locations, it also seemed prudent for historical reasons to bring current information together under one cover while this information was still fresh in everyone's mind.

One of the major differences in our ability to evaluate tree and forest responses to ice damage in 1998 compared with earlier events is the existence of various monitoring systems that provide valuable baseline information on prestorm conditions. The Ice Storm Symposium, therefore, also was viewed as a forum to exchange ideas about ways in which we might take advantage of extant programs such as Forest Health Monitoring and the North American Maple Project to more fully understand the consequences of this disturbance on forest health.

The content of these proceedings is a tribute to the extensive and timely responses to this event made by forestry agencies throughout the northeastern United States and eastern Canada.

Many people and several organizations were involved in the Ice Storm Symposium. I am especially beholden to the following agencies for assistance or financial support: the USDA Forest Service, Northeastern Area; the New York Center for Forestry Research and Development; the New York Society of American Foresters; the Office of Research Programs, New York State University College of Environmental Science and Forestry; Niagara Mohawk Power Corporation; and the New York State Department of Environmental Conservation. I would also like to thank Helen Thompson, Margaret Miller-Weeks, Lisa M. Fitzpatrick, and Tom Luther of the USDA Forest Service, Northeastern Area, for their assistance with the editing, desktop publishing, and GIS-generated graphics for this publication.

Douglas C. Allen
April 2001

Table of Contents

[1]These papers were not presented at the symposium. The authors were invited to contribute to these proceedings because the editors believe a summary of research underway in the United States to survey or evaluate the consequences of damage (Summary of Research Projects that Address Damage Caused by the Ice Storm of 1998) and an assessment of ice damage in Ontario's nonsugarbush stands (Monitoring Tree Health in Ontario After the Ice Storm) are important to complete our coverage of this storm and its impact on northeastern forests.

NEW YORK SOCIETY OF AMERICAN FORESTERS
ICE STORM SYMPOSIUM

Friday, January 29, 1999, Cortland, NY

In the wake of last year's ice storm, questions about forest health, economics, and management still confront forest managers and landowners. This symposium will examine the current status of research and management in the North Country.

Organized by the New York Society of American Foresters Forest Science and Technology Committee.

Symposium Sponsors

USDA Forest Service
New York Center for Forestry Research and Development
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8:00 — 8:10	**Introduction** — *Douglas C. Allen,* **SUNY College of Environmental Science and Forestry, Syracuse, NY**
8:10 — 8:40	**The Physics of Ice Formation** — *Kathy Jones,* **Researh Physical Scientist, Snow and Ice Branch, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Lab, Hanover, NH**
8:40 — 9:00	**History of Catastrophic Events to Northeastern Forests** — *Hugh Canham,* **Professor, Forest Economics and Historian NYSAF, SUNY College of Environmental Science and Forestry, Syracuse, NY**
9:00 — 9:40	**Impact on Sugarbushes and the Maple Syrup Industry** — *Lew Staats,* **Extension Associate, Maple Program, Cornell University, Lake Placid, NY, and** ***David Chapeskie*****, Agroforestry Specialist, Ontario Ministry of Agriculture, Kemptville, ON**
9:40 — 10:00	**Extent of Damage in New York and Department of Environmental Conservation's Response** — *Jim Beil,* **Assistant Director, Division of Lands and Forests, DEC, Albany, NY**
10:00 — 10:20	**Damage Survey & Assessment in New York State** — *Paul Manion,* **Professor, Forest Pathology, SUNY College of Environmental Science and Forestry, Syracuse, NY**
10:20 — 11:00	**Break**
11:00 — 11:30	**Damage Assessment on ARNEWS & NAMP Plots** — *Pierre DesRochers,* **Canadian Forest Service, Laurentian Forest Research Lab, Sainte-Foy, Quebec, and** *Douglas C. Allen,* **SUNY College of Environmental Science and Forestry, Syracuse, NY**
11:30 — 12:00	**USDA Forest Service Response for Damage Assessment and Landowner Assistance** — *Margaret Miller-Weeks,* **Ice Storm Assessment Coordinator, and** *Jim Linnane,* **Ice Storm Team Coordinator, USDA Forest Service, Durham, NH**
12:00 — 1:00	**Lunch**
1:00 — 1:30	**Genesis of the Ice Storm & Relation to El Niño** — *David Eichorn,* **Chief Meterologist, Channel 9, Syracuse, NY**
1:30 — 1:50	**NH Assessment & Response** — *Jennifer Bofinger,* **Division of Lands and Forests, Concord, NH**
1:50 — 2:10	**ME Assessment & Response** — *David Struble,* **Maine Forest Service, Augusta, ME**
2:10 — 2:30	**VT Assessment & Response** — *Ron Kelly,* **Department of Forests, Parks and Recreation, Morrisville, VT**
2:30 — 2:50	**Effects of Ice Damage to NY's Forest Industry & Industry Response** — *Steve Satterfield,* **Woodlands Manager, Finch, Pruyn & Co., Glens Falls, NY**
2:50 — 3:10	**Impact of Ice Damage on Forest Industry in New England & Recommended Forest Management Responses** — *Neil Lamson,* **Ice Storm Recovery Coordinator, USDA Forest Service, Waterbury, VT**
3:10 — 3:30	**Discussion**

Unit Conversion Table

To convert ...	Into ...	Multiply by ...
acres	hectares	0.4047
centimeters	inches	0.3937
feet	meters	0.3048
grams	ounces	0.035
hectares	acres	2.471
inches	centimeters	2.54
inches	millimeters	25.4
kilograms	pounds	2.2046
kilograms per hectare	pounds per acre	0.892
kilometers	miles	0.621
meters	feet	3.28
miles	kilometers	1.609
milligrams	ounces	0.000035
millimeters	inches	0.03937
ounces	grams	28.35
pounds	kilograms	0.4536
pounds per acre	kilograms per hectare	1.121

The Physics of Ice Formation: Ice on Trees

Kathleen F. Jones

Research Physical Scientist, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Snow and Ice Division, Hanover, NH

Abstract

Ice storms can cause severe damage to trees, affecting timber values, orchards, maple syrup production, parks and recreation lands, and municipal and residential plantings. In this paper a simple ice accretion model for forecasting or estimating the uniform radial ice thickness in freezing rainstorms is described. Methods for determining the uniform radial ice thickness from ice samples on branches are presented. Modeled ice thicknesses, from both this simple model and the more detailed Cold Regions Research and Engineering Laboratory (CRREL) model, as a result of the January 1998 ice storm are shown for weather stations in the United States and Canada. Using information on the distribution of branch and twig diameters for a single tree, the weight of ice on trees is determined as a function of two basic tree parameters—the total branch length and a characteristic branch diameter.

Introduction

The most widespread effect of freezing rain on people is slippery roads. Colder bridges and overpasses may be the first to develop a thin layer of ice, followed by highways and secondary roads, except in regions where the ground is relatively warm. These thin layers of ice lead to fender benders and more serious collisions, and schools are often closed because of public safety concerns. If freezing rain continues to fall, damage to trees occurs as small branches, large limbs, and even entire trees are broken by the weight of the accreted ice. In some storms, tree damage is exacerbated by gusty winds that may occur either with the precipitation or accompanying a cold front moving into the region following the storm. Ice storms occur even in the southern and southeastern United States, in regions that do not typically experience prolonged cold winter weather.

Fewer than 4 years before the January 1998 storm hit northern New York, New England, and the southern portions of Ontario, Quebec, and New Brunswick, a similarly severe freezing rainstorm struck a region extending from Texas through Louisiana, Arkansas, and Missouri across Mississippi, Alabama, Tennessee, Kentucky, and into the Carolinas. The ice storm and the resulting damage are described in NOAA (1994) and, for states with presidential disaster declarations (Mississippi, Alabama, Tennessee, and Kentucky), in Federal Emergency Management Agency hazard mitigation reports (FEMA 1994a,b,c,d). Both storms caused severe tree damage as well as prolonged power outages.

This paper reviews a simple ice accretion model for forecasting or estimating the uniform radial ice thickness in ice storms. Modeled ice thicknesses, from both this simple model and the more detailed CRREL model, are shown for weather stations in the United States and Canada for the January 1998 ice storm. Using information on the distribution of branch and twig diameters, the weight of ice on trees is calculated as a function of two basic tree parameters—the total branch length and a characteristic branch diameter.

Simple Ice Accretion Model

It is difficult to describe the amount of ice accreted on twigs and branches in an ice storm because the

cross-sectional shape of accretions varies greatly. Ice may freeze in a crescent (Figure 1a) or in a bulbous mass on one side of a branch (Figure 1b), or completely covering a branch with many icicles underneath (Figure 1c). Icicles form in relatively warm conditions when the precipitation freezes as it begins to drip off the branch. The failure of a tree or structure during an ice storm may cause the original accretion shape with icicles underneath to rotate to the side or top. Subsequently, as freezing rain continues to fall and ice continues to accrete, the cross-sectional shape may become rather complex (Figures 2a and 2b). A useful concept for describing the amount of ice is the equivalent uniform radial thickness. The uniform radial thickness of ice on a cylinder (an idealized branch) is the thickness the ice would have if it were spread uniformly around the circumference of the cylinder. The simple ice accretion model, based on simple physics and a number of empirical observations and assumptions, determines the uniform radial ice thickness from the amount of freezing rain and the wind speed.

(a) (b) (c)

Figure 1. Typical ice accretion shapes: (a) crescent of ice on a rail, January 8, 1998, east of Malone, NY (photo, Jones); (b) large accummulation on one side of a blade of grass, January 9, 1998, near Ogdensburg, NY (photo, N. Mulherin, CRREL); and (c) with icicles surrounding a twig, March 1991, near Ft. Drum, NY (photo, D. Fisk, CRREL)

(a) (b)

Figure 2. Examples of knobby ice accretions: (a) on a wire, February 1994, southeast Arkansas (photo, Entergy); (b) on a branch, February 1996, Paris Mountain, SC (photo, Jones)

First, consider rain falling with no wind. The raindrop trajectories are vertical, perpendicular to the horizontal ground. The same depth of rain falls on a sidewalk and a nearby street. If the weather is cold enough and the street and sidewalk are flat (so that the water does not pool or run off), the rainwater freezes and forms a uniform layer of ice that is the same thickness on both structures. If the density ρ_i of this ice is 0.9 grams/centimeter^3, a 10-millimeter rainfall results in a uniform ice layer 11 millimeters thick. The mass of ice on a 100-meter length of the wide street is substantially greater than the mass of ice on a 100-meter length of the much narrower sidewalk, but the ice thickness is the same on both.

Now extend this same argument to cylinders. Consider long cylinders of various diameters suspended horizontally above the ground in this same windless rainstorm. The 10 millimeters of rain that falls on the sidewalk and street also falls on each of these cylinders. If all the impinging water freezes, and it freezes in a uniform radial accretion, ice is spread uniformly over the surface of the cylinders. Because the circumference is a factor of π times the cylinder diameter, the uniform radial ice thickness t on each horizontal cylinder is

$$t = 10\frac{\rho_o}{\rho_i}\frac{1}{\pi} = 3.5 \text{ mm} \qquad (1)$$

where $\rho_o = 1.0$ gram/centimeter^3 is the density of water. As long as the ice accretes uniformly around the cylinders, the cylinder cross sections remain circular. Thus, the ratio of the diameter of each iced cylinder to its circumference remains $1/\pi$ throughout the freezing rainstorm, and the ice thicknesses are independent of cylinder diameter.

Typically, there is wind during freezing rainstorms, so the horizontal flux of windblown rain must also be included in the simple model. Best (1950) related liquid water content to precipitation rate, $W=0.067\,P^{0.846}$, where P is the precipitation rate in millimeters/hour and W is the liquid water content of the rain-filled air in grams/meter^3. Then the horizontal flux of rainwater is VW (grams/[meter^{2}second]), where V is the wind speed in meters/second. The total water flux w is obtained by converting to a consistent set of units and adding vectorally the horizontal flux of windblown rain to the vertical flux $P\rho_o$ (gram millimeter/[centimeter^{3}hour]) of falling rain:

$$w = [(0.1P\rho_o)^2 + (0.36VW)^2]^{1/2}$$
grams/(centimeter^{2}hour) (2)

The uniform radial ice thickness on a circular cylinder is then

$$t = \frac{N}{\rho_i \pi}[(P\rho_o)^2 + (3.6VW)^2]^{1/2} \text{ millimeter} \quad (3)$$

where N is the number of hours of freezing rain with precipitation rate P and wind speed V. A plot of t versus P and V for $N = 1$ hour is included in Jones (1998). Note that the uniform radial ice thickness does not depend on the diameter of the cylinder.

The simple model can be simplified further by linearizing the liquid water content formula $W=0.067\ P^{0.846}$ for the low precipitation rates associated with freezing rain and incorporating the values for π, ρ_o, and ρ_i in (3). Going one step farther and characterizing the storm by the total amount of freezing rain P_T and the average wind speed $\bar{V}$ (3) then becomes

$$t = 0.35P_t\left[1+\left(\frac{\bar{V}}{5}\right)^2\right]^{1/2} \quad (4)$$

This formulation shows that the effect of the windblown rain becomes as important as the falling rain when the wind speed reaches 5 meters/second. It provides an estimate for the accreted uniform ice thickness on a branch or twig that requires no more than paper and pencil for implementation and can be used with either the measured wind speed and precipitation amount or forecast weather data.

The two empirical observations used in the simple model have already been stated. The density of the ice formed from freezing rain is taken as 0.9 grams/centimeter^3. This value is based on the typically clear ice accretions that are observed and is less than the density of pure bubble-free ice (0.917 grams/centimeter^3). The second empirical observation relates the liquid water content W in rain to the precipitation rate using Best's formula $W = 0.067P^{0.864}$.

A number of assumptions are made in the simple model. First, it is assumed that the collision efficiency of the raindrops with the cylinder is 1. The relatively massive rain and drizzle drops, with diameters typically between 200 and 2,000 microns, travel in virtually straight-line trajectories even in low winds and collide with any object in their path. In contrast, the collision efficiency of cloud droplets, which are typically 5 to 50 microns in diameter, increases with droplet diameter and wind speed and decreases with the diameter of the cylinder and is usually less than 1 (see, for example, Finstad and others 1989). The second, often conservative, assumption is that all the drops of freezing rain impinging on the cylinder freeze. Detailed ice accretion models typically include a heat-balance calculation, based on numerous assumptions and empirical observations and requiring air temperature and dew point data, to determine the fraction of the impinging precipitation that freezes. Whether or not the drops of freezing rain are supercooled has little effect on the rate of freezing or the freezing fraction: 334 Joules of heat must be removed to freeze 1 gram of water at 0 °C. If the raindrops are supercooled, warming 1 gram of water to 0 °C extracts only 4.2 Joule of heat for each degree of supercooling. Raindrops supercooled to -5 °C, for example, would extract only 6 percent of the heat that must be removed to freeze that amount of water. However, convective and evaporative cooling from wind blowing by the cylinder are efficient mechanisms for freezing the impinging water. The third assumption is that ice accretes uniformly around the circumference of the cylinder. As was shown by the photos of various ice shapes on branches and wires in Figures 1a through 2b, this is a simplification of reality and is not necessarily conservative. However, assume a uniform radial accretion is consistent with the level of detail in this simple model. The final, often conservative, assumption is that the cylinder is horizontal and perpendicular to the wind direction. For a cylinder with its axis parallel to the wind direction, the second term in (4) is zero and for a vertical cylinder the first term in (4) is zero. Ultimately, the actual uniform radial thickness of ice accreted on a particular branch will depend on the local precipitation amount and wind speed profile, the exposure of that branch to wind and rain, its orientation with respect to horizontal and to the local wind direction, the air temperature and humidity, and numerous other less significant factors.

Using (4), uniform ice thicknesses can be determined for any combination of precipitation amount and wind speed, to determine, for example, the potential severity of a forecast ice storm. For $P_T = 20$ millimeters and $\overline{V} = 5$ meters/second, the uniform ice thickness is 10 millimeters. For much higher winds, say $\overline{V} = 15$ meters/second but the same amount of freezing rain, $t = 22$ millimeters, pointing out the significant effect of wind on the accreted ice thickness. For a given uniform ice thickness the mass of ice on a branch depends on the diameter d and length L of the branch:

$$m = \rho_i \pi (t^2 + dt) L \qquad (5)$$

Uniform ice thicknesses of 10 millimeters on 1-meter long branches with diameters of 10 and 25 millimeters, for example, weigh 0.56 and 0.99 kilograms, respectively. Solving (5) for t

$$t = -\frac{d}{2} + \left[\frac{d^2}{4} + \frac{m}{\rho_i \pi L} \right]^{1/2} \qquad (6)$$

allows the uniform radial ice thickness to be calculated from the mass m and length L of an ice sample on a branch with diameter d. The volume $v = m/\rho_i$ of the melted ice or the area $a = m/\rho_i L$ of the ice sample cross section may also be substituted in (6) to determine the uniform radial thickness of the ice on the branch. Any consistent set of units can be used in calculating ice mass in (5) and ice thickness in (6).

January 1998 Ice Storm

Using both the simple model and the more detailed and less conservative CRREL model (Jones 1996), uniform radial ice thicknesses were determined for the January 5–10, 1998, ice storm at weather stations in the United States and Canada (Figure 3). The lower value at each station is the CRREL model result and the higher value is the simple model result. At the stations where only one value is reported, the results from the two models are the same. Local variations in the wind speed and amount and type (rain, snow, freezing rain, ice pellets) of precipitation can cause significant variations in uniform radial ice thicknesses in the regions between weather stations. In Utica, NY, at the Cold Regions Research and Engineering Laboratory (CRREL) in the Connecticut River Valley in New Hampshire, and at the summit of Mount Washington (1,920 meters) in New Hampshire, the air temperature remained above freezing throughout the storm, so no ice accreted. In Watertown, NY, Sherbrooke, Quebec, and Portland, ME, the significant differences between the CRREL model and simple model results are due to the relatively warm temperatures at those weather stations. Near these weather stations at sites where the air temperature was only 1 or 2 °C colder than at the station, trees are likely to have been subjected to the higher simple model ice loads. In Houlton, ME, the raindrops froze as they fell through a thick layer of cold air at the surface. The resulting ice pellets accumulated in a thick layer on the ground

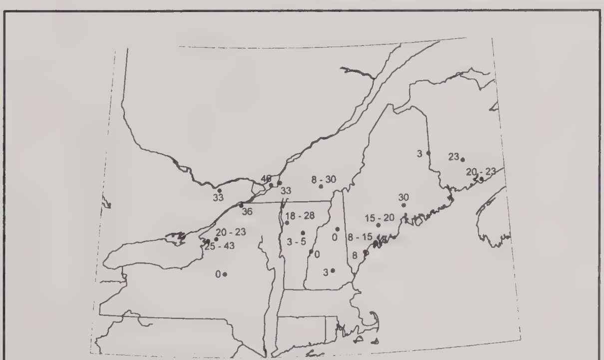

Figure 3. CRREL model and simple model uniform radial ice thicknesses (millimeters) for the ice storm of January 5–10, 1998

and on roofs, but did not stick to trees and wires. In Vermont and New Hampshire, freezing rain fell only at moderately high elevations, typically between about 400 and 1,100 meters. Tree damage ranged from light to severe across the states and provinces hit by the storm. This storm was similar in severity to the December 1929 ice storm, which also extended from New York to Maine.

Ice Loads on Trees

Harshberger (1904) presented data on two "exceptionally destructive" ice storms that hit the region around Philadelphia, PA, in February and December of 1902. He described the ice loads on branches in terms of the ratio of the mass of ice on the branch to the mass of the branch. For the February storm he quotes other researchers' results. At Horticultural Hall, the branch of an oriental plane tree was encased in ice that weighed 100 times the branch itself, in Doylestown ice on a twig weighed 26 times the twig, and on Staten Island twigs 3 millimeters in diameter carried 30 to 40 times their weight in ice. In the December storm Harshberger measured ice masses and branch or twig masses and obtained ratios between 3 and 23 for a variety of species of trees in the Botanic Garden of the University of Pennsylvania.

To determine uniform ice thicknesses from the information Harshberger provides, the ratio of ice mass to branch mass was calculated using (5) for uniform ice thicknesses up to 35 millimeters on maple branches and twigs with diameters ranging from 3 to 25 millimeters (Figure 4). A wood density of 0.8 grams/centimeter^3 was assumed. The 30 to 40 ice mass to twig mass ratio for 3-millimeter twigs reported in Harshberger corresponds to uniform ice thicknesses of 6 or 7 millimeters. This same uniform thickness of ice on a 25-millimeter diameter branch is not nearly as dramatic, with an ice to wood mass ratio of only 3:2. A ratio of 100 for ice on a maple branch corresponds to a uniform ice thickness that is 4.2 times the diameter of the branch, emphasizing the importance of noting the branch diameter when reporting ice loads in this way.

It is interesting to estimate the total ice load on a tree. This can be done using (2) if the diameters and lengths of the tree's branches and twigs are known. The cumulative *L(d)* relationship was determined for a convenient recently expired tree on Dartmouth College property. The 8.5-meter-tall ash was planted in 1986 in a small grassy island between a parking lot and the road. The trunk was 26.6 centimeters in diameter at breast height. The tree was cut at ground level and, over the next few months, dismantled into single twig and branch components (Figure 5). The length and average diameter of each component were measured. The many small twigs of each main branch were sorted into groups of similar lengths and diameters, and the average length, average diameter, and number of twigs were recorded. The measurements were compiled by diameter and are plotted in Figure 6, which excludes only the trunk of the tree. In comparison, Whittacker and Woodwell (1967) described tree and woody plant branches in terms of the current twig diameter d_t, the number of times g the branch segment had divided into two smaller-diameter branch segments, the branch taper factor f, which is the ratio of each generation's branch diameter to that of the next generation, and the average length of each branch segment L_s. Using this formulation the branch diameters form a decreasing sequence

$$d_t f^g, d_t f^{g-1}, d_t f^{g-2}, \ldots, d_t \quad (7)$$

with corresponding branch lengths

$$L_s, 2L_s, 4L_s, \ldots, 2^{g-1} L_s \quad (8)$$

In this formulation the smallest diameter twigs have the longest total branch length, which differs from the distribution of length with diameter shown in Figure 6. However, as Whittacker and Woodwell's values are averages for many branches of many trees of each species, it is not unlikely that their raw data on lengths and diameters would show a distribution similar to that for the Dartmouth tree.

As the ultimate goal was to determine potential ice loads on trees from freezing rainstorms, an analytic relationship for *L(d)* was determined. The equation

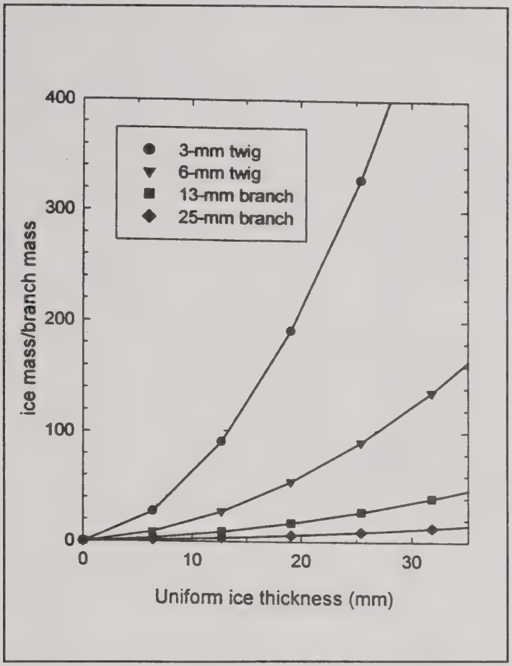

Figure 4. Ratio of ice mass to mass of maple branch (wood density 0.8 grams/centimeter^3) for uniform ice thicknesses up to 35 millimeters

Figure 5. Trunk, branches, and twigs of the Dartmouth tree

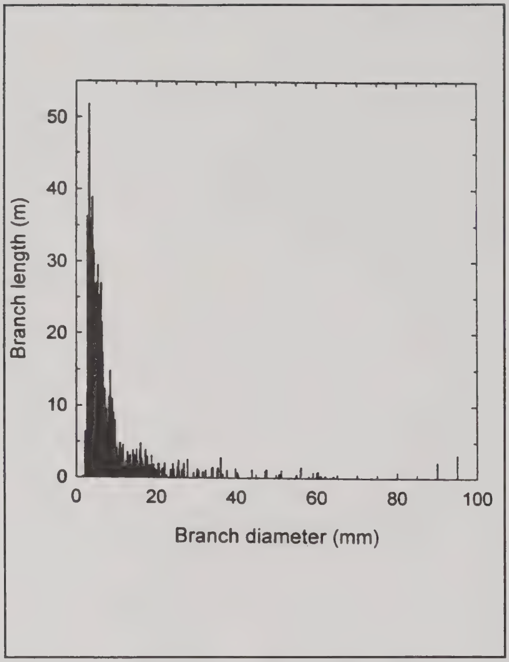

Figure 6. Distribution of total branch length with branch diameter for the Dartmouth tree

$$L(d) = L_T \exp\left(-\frac{d_0^2}{d^2}\right) \qquad (9)$$

fit the data very well (Figure 7), with a total branch length L_T= 1,538 meters and characteristic diameter d_o = 4.1 millimeters for this small ash. The total ice load M on a tree can now be determined from (5), written as an incremental mass dm and using the derivative of (9) for dL:

$$\begin{aligned} M(t) &= \int_{d\min}^{d\max} \rho_i \pi (t^2 + xt) L_T \left(\frac{-2d_0^2}{x^3}\right) \exp\left(-\frac{d_0^2}{x^2}\right) dx \\ &= \rho_i \pi L_T \left(t^2 \exp\left(-\frac{d_0^2}{x^2}\right) - d_0 t \sqrt{\pi}\, erf\left(\frac{d_0}{x}\right)\right)\Bigg|_{d\min}^{d\max} \\ &= \rho_i \pi L_T \left(t^2 + d_0 \sqrt{\pi}\, t\right) \end{aligned} \qquad (10)$$

where the minimum and maximum branch diameters, d_{min} and d_{max}, have been set to 0 and ∞, respectively, in the final result, without loss of accuracy. The relationship between ice load and uniform ice thickness for the Dartmouth tree is shown in Figure 8. The mass of the tree, assuming a wood density of 0.72 grams/centimeter³, was estimated as 213 kilograms. On the right-hand vertical axis in Figure 8 the ice mass is shown as a multiple of the tree mass. Uniform radial ice thicknesses of 10 and 25 millimeters result in ice loads of 750 and 3,508 kilograms, which are 3.5 and 16.5, respectively, times the mass of the tree.

The tree parameters L_T and d_o will vary with the tree species, age, size, exposure to the sun, and proximity to other trees. The failure of a particular ice-covered tree or branch also depends on the strength and brittleness of the wood, whether the branching pattern is decurrent or excurrent, the presence of included bark in branch junctures, the shape of the crown, and damage from human activities, disease, insects, and prior ice and wind storms (Hauer and others 1994). Uniform thicknesses of as little as 6 millimeters of ice have been observed to cause significant tree damage.

Summary

A simple ice accretion model was presented that can be used for estimating ice loads in anticipated freezing rainstorms using the forecast precipitation amount and wind speed. The model shows that the uniform radial ice thickness does not depend on the diameter of the ice-covered branch; however, for a given uniform ice thickness the ice mass increases with the branch diameter. A number of formulas for determining the uniform radial ice thickness from measurements of an ice sample on a branch were presented. From information on the distribution of branch and twig diameters for one urban tree, a general formulation for branch length distribution was obtained that depends on the total branch length and a characteristic branch diameter. This general formulation was used to determine the total ice load on a tree, which depends linearly on the total length of the branches and twigs, for any uniform radial ice thickness. This supports the observation of Hauer and others (1994) that trees with a fine branching pattern are more vulnerable to ice storm damage than those with coarse branching.

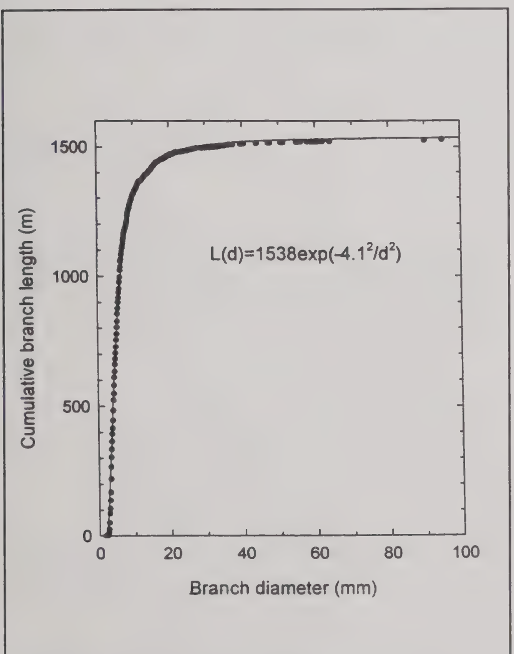

Figure 7. Cumulative branch length and best-fit curve for the Dartmouth tree

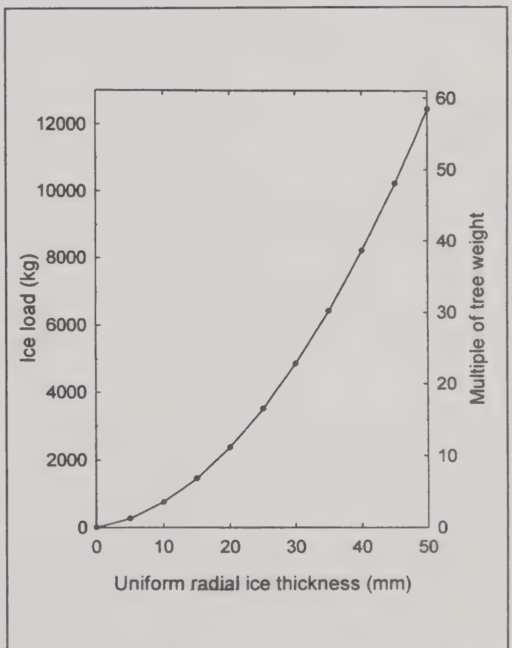

Figure 8. Dependence of ice load on uniform ice thickness for the Dartmouth tree

Acknowledgments

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Catastrophes, Shocks, and Other Disturbances to New York Forests

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Abstract

The forests of New York State have been subjected to rather sudden impacts throughout history. These impacts, or shocks, come from human-made and nonhuman events. Indeed, many of the most significant shocks to New York's forests over the last 300 years have been caused by human activities. This paper traces the most significant events that have shaped the forests of New York from Colonial times to the present. In this context, the ice storm of 1998 was only one incident in a chain of many disturbances.

Introduction

The ice storm in the North Country of New York State in January of 1998 prompted several studies of its effects on the forest and associated resources. As one thinks about similar incidents, immediately other weather-related events across the state come to mind. However, one quickly realizes that the forests of New York have almost constantly been subjected to disturbances of one kind or another. From an historical perspective, it is instructive to consider the following "shocks" to the forest resources of New York State. The list is incomplete and, in the interest of time and space, does not start with the Ice Age. The purpose is to highlight the most extensive and intensive disturbances that have occurred since the late 1700's.

Forest Disturbances

Land Clearing and European Settlement (late 1700's and early 1800's)—The clearing of land for agriculture was probably the biggest shock New York forests have endured. Also, at this time the remaining forest was first extensively harvested for wood products.

The Erie Canal and Rail Transportation (mid- to late 1800's)—These events, while not directly impacting the forests, set the foundations for urbanization of the state. In addition, the canal opened the Midwest with its more fertile farm land, thus leading to abandonment of agricultural land in New York with subsequent regrowth of forests. This conversion continues in many regions of New York today (Alerich and Drake 1995, Thompson 1966).

Great Fires and Massive Timber Harvesting in the Adirondacks (mid- to late 1800's, early 1900's)—Today the effects of those early fires are hard to detect but at the time they were a catastrophe. In addition, the massive harvesting of pine, spruce, and fir led to changes in forest composition, transportation systems, and the development of new communities (Donaldson 1921).

The Forest Preserve (late 1800's)—This was a definite shock in that it effectively froze human intervention on millions of acres of forest land. Subsequent species and habitat changes have greatly modified these forests compared to systems under more frequent human intervention.

Invention of the Linn Tractor (1920's and 1930's)—This seemingly innocuous invention changed the pace of timber harvesting in the state, particularly in the more remote Adirondacks, and led to more timber being harvested, and at a faster pace. Subsequent species conversion and road developments led to habitat changes.

The 1938 Hurricane (1938)—This hurricane was more devastating in New England, but it also affected the forests of New York.

Post-World War II Property Boom (1950's to the present)—Starting after World War II and continuing through today, there has been a massive shift in the ownership of New York's forests away from farmers to an extremely diverse set of private nonindustrial owners. These new owners with their diverse manage management objectives, or lack thereof, have produced many changes in New York's forests (Birch 1983, Canham 1973).

The Chain Saw (1950's and 1960's)—It has been said that the internal combustion engine is one of the greatest inventions of the 20th century. Certainly, the embodiment of a gasoline engine in a lightweight chaindriven saw has been one of the greatest "shocks" or events leading to forest change in the world. It was slow to be introduced, and articles in the New York Forester magazine from the 1950's and early 1960's both praised and denounced the chain saw (New York Forester). Some said it was a fad, others praised it, some said it would lead to complete denuding of the state. In any event it revolutionized tree cutting whether for timber harvest, improvement thinning, wildlife habitat, or recreation development.

The 1950 Hurricane (November 1950)—Some of the foresters in New York State still remember the 1950 hurricane, not so much for its direct effect on forests but for the subsequent horrendous fire danger, the special legislative bills to allow salvage on the Forest Preserve, and the notorious Cold River Fire that followed. This hurricane probably caused more widespread nonhuman changes in the Adirondacks than any other event. Acres of spruce, pine, and fir were toppled, often in inaccessible areas. The following summers much of the Forest Preserve was closed to hikers due to blocked trails and the extreme fire danger. The state legislature passed emergency legislation allowing salvage on parts of the preserve, and several young foresters got their initial experiences working for New York State by supervising these harvests (Fosburgh 1959).

Use of Hardwoods for Paper (1950's)—With the invention of the semichemical pulping process, hardwood tree species could be used efficiently for pulp for paper making. There are anecdotes of foresters girdling or otherwise eliminating hardwoods to favor spruce one year in a stand, then the next year an adjacent stand, girdling the spruce to favor the hardwoods. The changes in harvesting and forest management have been dramatic (Canham and Armstrong 1968).

Gypsy Moth Outbreaks (1960's to 1980's)—The gypsy moth caused initial widespread defoliation in eastern New York including the southern Adirondacks, Hudson Valley, and Catskills. The moth has been with us ever since, but in recent years there have not been the massive defoliations like those that occurred in earlier decades. Heavy, repeated defoliation killed white pine, hemlock, and species of favored hardwoods such as oak. In many cases this disrupted forest management plans and altered stand composition (Campbell 1979, Turner 1963).

Oak Furniture Mania (1970's to the present)—Many foresters can remember when oak was virtually a "weed species" as far as timber was concerned. Its price was similar to beech and soft maple. Then, in the early 1970's, people's preferences for furniture and cabinets changed. Almost overnight, loggers were revisiting old harvested areas and other stands in search for oak.

Export Markets for Wood (1970's to present)—In recent decades the export demand for New York logs and lumber have increased dramatically. With this increase have come large price increases and more interest in finding clear long logs of many species. Sawmills have found that standard U.S. lumber grades may not meet the requirements of European buyers. This in turn has lead to rethinking what constitutes high value logs and trees.

Mesoscale Convective Event (popularly know as microbursts) (summer 1996)—This was another nonhuman weather-related event which, according to several meteorologists, was a collection of thunderstorms that moved across northern New

York. The effects were similar to the 1950 hurricane but much more localized in small patches.

Ice Storm (winter 1998)—Ice storms have affected the forests of New York since the Ice Age! Many north facing slopes on the Southern Tier have visible histories of repeated ice damage. What made the recent one in northern New York so spectacular was the size of the area affected, the media attention, and the devastating effects on human habitation. The long-term shock to the forest system is currently under study.

Conclusions

The above list demonstrates the multifaceted nature of shocks to New York forests. Human-related events have caused as much change as have weather and other nonhuman events. Have these shocks been "good" or "bad"? This question cannot be answered in this simplistic manner. The value, both in amount and in kind, depends on the value system and things that we as humans want from forests.

Other events could be listed that are ongoing. For example, an unusually early spring and dry weather will set conditions for several forest fires. The imminent change of ownership of the Champion Pulp and Paper Mill, the uncertainty of continued operation of the Lyonsdale Energy Facility, and the loss of chip markets at Proctor and Gamble's plant in Pennsylvania will all change how we manage New York forests and will lead to further changes. The Empire Forest is indeed a dynamic system.

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The 1998 Ice Storm: Its Impact and Recovery Program in New York

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Abstract

The January 1998 ice storm severely impacted sugarbush stands in several states and Canadian provinces. The six-county region of northern New York was declared a Federal disaster area. In response, an ambitious effort by Cornell University, with funding and support from the USDA Forest Service Northeastern Area and the New York State Department of Environmental Conservation, has been underway to research the recovery of sugarbush stands, evaluate sap yield from ice damaged sugar maples, and develop silvicultural guidelines for managing impacted sugarbushes. A program by Cornell Cooperative Extension for development of materials and distribution to maple producers complements the research.

Introduction

During January 1998, a weather event of major significance took place in the northeastern region of North America. The infamous "January 1998 Ice Storm" caused power outages that affected thousands of homes and businesses for days, and in some areas weeks, before power could be restored. The storm and its aftermath also affected urban and rural forest trees in the region. The widespread damage in several states and Canadian provinces is recognized, but this report focuses on the impact of the storm to the maple industry of New York State and the programs that have developed in response.

Maple producers in New York State were especially hard hit by the January ice storm. As in other parts of the northeastern United States, many maple producers there rely on syrup for a significant portion of their annual income. In two of the six counties, preliminary estimates suggested a near total loss of the 1998 production year. A brief characterization of the weather factors leading up to the damage sequence will provide a better understanding of the severity of the storm and its impact. Rainfall during January 5–9 totaled 7.5 to 12.5 centimeters (3 to 5 inches) in northern New York State according to local meteorologists. The temperature remained near or at 0 °C (32 °F) at this time resulting in 5 to 10 centimeters (2 to 4 inches) of ice accumulation on structures such as utility poles and power lines, and branches of trees and shrubs. Most severe ice build-up (glazing) developed below 365 meters (1,200 feet) elevation. At higher elevations, glazing occurred in pockets that followed waterways and on northeasterly slopes. Tree branches collapsed under the heavy glaze build-up, severed and fell to the ground, or remained hanging in the crowns.

The six northern counties of Clinton, Essex, Franklin, Jefferson, Lewis, and St. Lawrence were declared Federal disaster areas immediately following the storm. The six-county region accounts for nearly 35 percent of New York's annual syrup production and about 25 percent of the state's maple syrup producers (Staats 1998a). The number of taps not placed for the 1998 maple season as a direct result of the January 1998 ice storm is estimated at 380,000 (New York Agricultural Statistics Service 1998). This figure also includes a small percentage of taps in Wyoming County in western New York, which incurred much less ice damage. Production loss from the number of taps not placed for the 1998 season had a potential loss of income of over $3 million for the region. The counties of Clinton, Franklin, and St. Lawrence

reported that damage was noted in over 90 percent of sugarbushes. The extent of damage varied across the region, but 60 percent of the producers reported damage classified as heavy (over 50 percent live crown loss, broken main trunks, or uprooting).

The storm impacted the maple industry in a number of ways. The most immediately apparent affect was loss of accessibility to and within sugarbushes from fallen tree tops and branch debris in access roads and throughout sugarbushes. Current technology for maple sap collection uses permanently established plastic tubing lines. These lines are suspended throughout the sugarbush in a vast network allowing efficient sap transfer to collection points. Along with loss of access, crown debris also removed tubing systems and accumulated over the downed tubing lines inhibiting reestablishment. This sequence damaged or destroyed lines and fittings. Ice build-up on the debris, additional snowfall, and hanging dead branches made debris removal and tubing installation very hazardous. Beyond the large task of clean-up of debris and restoration or replacement of sap collection systems, producers were uncertain of the benefits and effects of tapping trees with substantial crown damage and loss.

Response and Recovery

Immediately following the storm, maple producers sought answers to management and operational questions. The ice storm was an ecological disturbance of a magnitude most had never experienced. In response, a committee of specialists and scientists provided interim guidelines to assist maple producers with decision making for tapping during the 1998 maple production season (Table 1) and for managing ice-damaged sugarbush stands (Staats 1998b). Several factors were considered in formulating the tapping guidelines for sugar maples damaged by ice. As a result of damage from broken branches, high demands on individual tree energy would be required for repair and compartmentalization of wound areas. It was thought that tapping more conservatively compared to pre-storm levels could help to reduce the amount of wound area and thus energy demands on the tree. Further, wounds resulting from broken branches could serve as potential sites for the loss of abnormally high amounts of sap for weeks immediately following the ice storm.

Table 1. Suggested tapping guidelines for sugar maples damaged by ice

Percent crown loss	Suggested treatment
0–10 percent	Use current tapping guidelines; number of taps per tree by tree diameter (d.b.h.) during pre-storm production
11–50 percent	Conservative tapping; one tap for minimum d.b.h. of 30.5 centimeters (12 inches); two taps for minimum of 46 centimeters (18 inches)
51–75 percent	No tapping; extensive would area with potential for tree survival
> 76 percent	High risk of probability that the tree will die; tapping is the option of the producer

The following suggestions in support of management decision making were also provided (Allen and others 1998):

1. Practice safety at all times while entering and working in damaged stands. Wear a hard hat and other proper safety gear.
2. Be patient when making management decisions; stand back and take a look.
3. Consult a forester—either a New York State Department of Environmental Conservation (NYS DEC) forester or a consulting forester (lists of foresters are available at NYS DEC offices).
4. Avoid debris removal activities and harvesting of damaged trees during periods when soils are soft or wet to minimize mechanical damage to root systems and avoid above-ground damage to crop trees.
5. Wait for one or more growing seasons to decide which damaged trees should be removed.
6. Severely damaged trees (uprooted, complete loss of crown or severed trunk, severe splitting with major structural damage) should be removed.

Programs and Projects

Crown Loss and Sap Yield

Questions from maple producers as to whether to tap ice-damaged trees for the 1998 season and beyond prompted an extensive literature search. With no documentation regarding the effects of tapping trees recently damaged by glaze storms, a study to examine the sap volume yield and sugar concentration from individual sugar maples categorized by percent crown loss was initiated for the 1998 production season. The study site, located at an ice-damaged sugarbush near Lake Placid and near the Uihlein Sugar Maple Field Station of Cornell University, provides experimental layout and sap data collection readily accessible for researchers based at the field station. The study design includes 35 trees (40 taps) categorized into four damage levels: 0–10 percent, 11–25 percent, 26–50 percent, and 51–75 percent crown loss.

In addition to data collected during the 1998 sap production season, the study will be continued for 1999 and beyond or until a conclusion from the data can be clearly demonstrated. Anecdotal information from maple producers following the 1991 ice storm near Rochester, NY, suggested that moderately damaged trees retained their original production levels within a few years. The current design will allow us to document to what extent and how quickly damaged trees recover production.

Sugarbush Recovery Monitoring

Little information is available regarding the recovery of ice-damaged sugar maples that have been tapped and silviculturally managed for sap production. Research to document pre- and post-storm conditions in sugarbushes was initiated during early 1998. Permanent plots placed in sugarbushes monitored by the North American Maple Project and those used by the NYS DEC Survey of Sugarbush Health (Allen and Cymbala 1994) were examined, but it was found that very few plots received ice damage. Beginning with an evaluation of sugarbush damage by air and ground surveys from February through June, a recovery monitoring project specifically for sugarbush stands was initiated by Cornell University in cooperation with the NYS DEC, the USDA Forest Service, and Cornell Cooperative Extension.

During the summer of 1998, 60 plots in 12 locations were established throughout northern New York State. Locations were selected based on an array of criteria including accessibility, landowner cooperation, and damage level. Following a plot protocol developed by the Ice Storm Damage Assessment Group and William Ciesla of Forest Health Management International in July 1998, the plots provide a representative picture of pre- and post-storm health, tree damage estimates, individual tree characteristics indicative of health and vigor, past management history, and ecological factors. Also, each plot location was mapped and photographed. It is intended that these permanent plots will be remeasured for at least 4 consecutive years. Data will be analyzed and reported annually, and a Best Management Practices guide for ice-damaged sugarbush stands will be developed after

additional years of monitoring and evaluation. Plots serve the dual function of research data collection and use as demonstration areas for Cooperative Extension educational programs.

Information Shared Through Cooperative Extension Programs

In response to concerns voiced by maple producers, workshops were held in Clinton and St. Lawrence Counties during August 1998. Preliminary workshops had been held by Cornell Cooperative Extension shortly after the ice storm. For each workshop, information was presented during an inside classroom session on chainsaw safety, Farm Service Agency programs for assistance to maple producers, and silvicultural considerations for managing ice-damaged sugarbush stands. A permanent plot established for the sugarbush monitoring program was visited during the afternoon session. Plot design and establishment and an exercise for estimating crown damage loss using specific trees was demonstrated. At each workshop, ample time was provided for questions and sharing of experience. It is intended that additional workshops will be held each year as more information is acquired and will benefit the recovery of damaged sugarbush stands.

Alternative sources of income for maple producers and landowners are being explored while sugar maple stand productivity has been reduced. Recreation, wildlife, and intercropping of specialty crops such as mushrooms and ginseng in sugarbush stands may help fill the economic loss from the damaged trees and reduced production. Initially, workshops were offered to assess interest among maple producers and to identify potential landowners to serve as hosts for demonstration areas. To evaluate and demonstrate the feasibility of growing alternative crops in sugarbush stands in northern New York State, demonstration plots of ginseng and mushrooms were established during 1998 at the Uihlein Sugar Maple Field Station at Lake Placid. Plots will be monitored and evaluated at a future time.

In addition to attending workshops and visits to demonstration sugarbushes, maple producers received a copy of the booklet *Trees and Ice—After the Ice Storm of 1998* (Winship and Smallidge 1998) and other publications. Maple producers in the region were given an update on the ice storm during both the 1998 and 1999 Cornell Maple Production Satellite Schools.

Summary and Future Plans

Following the 1998 maple season, 70 percent of producers who reported damage felt they would tap during the 1999 season, 15 percent were uncertain, and 15 percent stated they would not tap during 1999 (New York Agricultural Statistics Service 1998). Those who gave a positive response were not sure as to what extent they would tap and expressed a desire to view their trees after the 1998 growing season before making a decision to tap in 1999. In addition to the programs previously discussed, alternatives to provide sources of income for maple producers and landowners are being explored while sugar maple stand productivity has been reduced. As indicated, Cornell University, the USDA Forest Service, and NYS DEC support is available to continue monitoring the sap production and sugarbush plots. Also, maple producers will be invited to participate in future workshops and to visit demonstration areas. Current research projects are assessing how maple producers reacted to the educational and technical assistance programs during 1998 to allow refinements in delivery in the future.

Acknowledgments

The author recognizes the valuable discussion and consultation with several key individuals immediately following the storm and throughout the recovery period: Dr. Douglas Allen, Dr. David Houston, Mr. Clarence Coons, Mr. David Chapeskie, and Dr. Peter Smallidge. Funding from Cornell University-College of Agriculture and Life Sciences, Cornell Cooperative Extension, the USDA Forest Service Northeastern Area State and Private Forestry, and the New York State Department of Environmental Conservation Division of Lands and Forests is greatly appreciated. In support of the field program activities, the following individuals are acknowledged: Jennifer Keefer, Jennifer Koegl,

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Ice Storm Damage to Sugarbushes in Ontario

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Introduction

In Ontario, there are 2,274 maple producers operating 1,147,500 taps (Statistics Canada 1996). The sale of syrup and other maple products is worth an estimated $15 million to the economy annually, and prospects for growth of the industry are very good. An additional value in spin-offs to small communities throughout rural southern and central Ontario and emerging ecotourism values must be recognized. In Ontario, the size of maple syrup operations ranges from a few hundred taps to about 20,000 taps. In recent years, farmers have increasingly looked at all opportunities to generate income on the farm, including maple syrup, to develop and maintain strong farm enterprises. There is also a strong, albeit more intrinsic, value placed on maintaining the family tradition as well as the love of making this natural product.

Effects of the Ice Storm

The ice storm of 1998 was unprecedented in its scale and intensity with its main impact in Canada being in eastern Ontario and western Quebec (Figure 1). Previous ice storms were more limited in their geographic extent, and their impact was not well documented. The 1998 storm dumped as much as 100 millimeters of freezing rain on central and eastern Canada over the period of January 4–10, 1998. In parts of the affected area, the ice stayed on the trees for as long as 3 weeks.

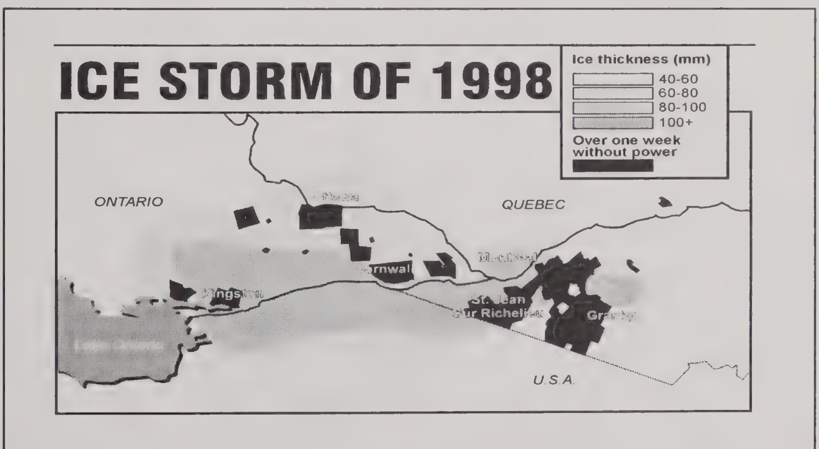

Figure 1. The approximate impact zone of the 1998 ice storm in Ontario and Quebec (data on file, Statistics Canada, Ottawa, ON)

The ice storm of 1998 affected approximately 25 percent of the commercial maple syrup industry operating about 300,000 taps in Ontario. The damage was confined to eastern Ontario; zones showing the approximate severity of damage are illustrated in Figure 2.

In 1998, the Ontario Ministry of Agriculture, Food and Rural Affairs implemented a very comprehensive on-the-ground evaluation of ice damage to sugarbushes in the total area impacted by ice in eastern Ontario. Trained technical staff working in teams of two estimated the loss of live crown to maple trees in about 278 commercial

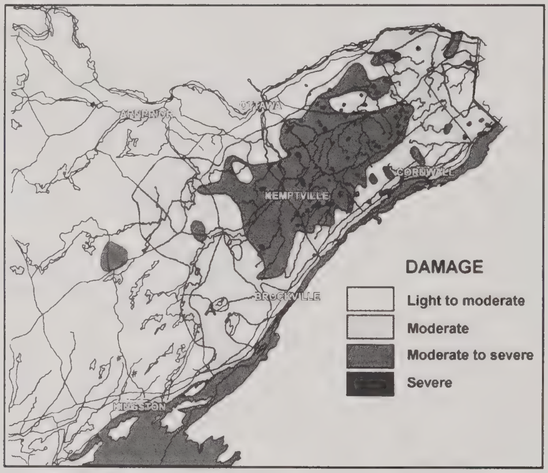

Figure 2. The degree of ice damage to forests in eastern Ontario as derived from aerial mapping (unpublished data on file, Ministry of Natural Resources and Natural Resources Canada, Kemptville, ON)

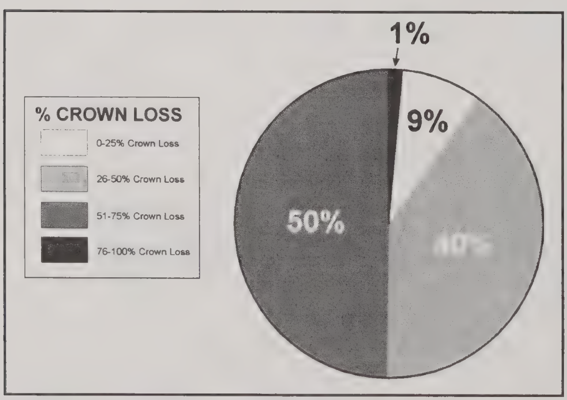

Figure 3. The average live crown loss for 278 sugarbushes in eastern Ontario as derived from comprehensive ground surveys (derived from Tree Assessment Program information, Ontario Ministry of Agriculture, Food and Rural Affairs, Kemptville, ON)

sugarbushes affected by the ice storm. The results from the evaluation of ice damage to tapped maple trees greater than 25 centimeters in diameter are summarized in Figure 3. Fifty-one percent of the 278 sugarbushes examined suffered at least 50 percent loss of live crown.

From the damage assessments, it was apparent that damage varied greatly from sugarbush to sugarbush. Important factors affecting the degree of damage included exposure to northeast winds, stand density, physical characteristics of the trees (i.e., strength of branches, architecture of the crown, size of the tree, etc.), and the amount of time the ice stayed on the trees.

Saplings were often bent to varying degrees. Pole-sized trees often broke from the weight of the ice, and larger trees suffered broken branches and occasionally damaged main stems and uprooting.

Recovery From the Ice Storm

In Ontario, many maple producers, while dismayed by the impact of the ice storm, were quick to begin clean-up operations. Many producers hoped to be operational, at least in part, for the 1998 season. It was a very big task to clean up after the ice storm, and emphasis was placed on clean-up for reasons of access and safety.

The Ontario Maple Syrup Producers Association worked closely with the Ontario Ministry of Agriculture, Food and Rural Affairs and other agencies to outline how the government, in partnership with the organized industry, could help the industry recover. Because of the scale and intensity of the damage, the ice storm was declared a national disaster, and disaster relief assistance was made available. Consequently, commercial maple producers were eligible for disaster relief assistance to cover the following items:

- Clean-up to restore access to the sugarbush and remove critical safety hazards
- Restoration or replacement of damaged plastic tubing (mainline and lateral lines)
- Financial compensation for damaged or destroyed maple trees
- Assessment of damage to maple trees and comprehensive inventory of the damaged sugarbush
- Development of management guidelines for the restoration of ice-damaged sugarbushes
- Implementation of applied research designed to determine the effect of ice storm damage on the health and productivity of sugarbushes.

Assistance with clean-up and restorative silviculture is also being provided by Human Resources Development Canada. This program offers training to work crews as well as productive employment. Some producers received assistance with clean-up from volunteer groups (e.g., Mennonites), which was very helpful.

The objective of these assistance programs is to help the maple industry recover as quickly as possible. It is recognized that it will take from a few years to about 40 years for individual sugarbushes to recover, depending on the degree of damage. It is expected that recovery of ice-damaged sugarbushes will depend on a number of important factors, including health of the maple trees following the ice storm, degree of ice damage, presence of other stressors, and weather events following the ice storm.

Where the damage is moderate to severe, many maple producers are applying a conservative approach to tapping their trees as recommended in tapping guidelines issued by the Ontario government (Chapeskie and Nielsen 1998). These guidelines also encourage producers to carefully monitor recovery. Harvesting all but the most severely damaged maple trees is discouraged until their potential to recoup can be gauged from early signs of recovery (i.e., sprouting of new shoots).

The impact of the ice storm on the short-term and long-term productivity of sugarbushes is currently unknown. Likewise, we can only speculate on the length of recovery period for ice-damaged sugarbushes (Coons 1999). Research currently underway in Ontario and in other jurisdictions is

designed to relate the degree of ice damage to sap sweetness and sap volume yields (Lautenschlager and Nielsen 1999).

Anecdotal evidence and growth information available suggest that full recovery will take from several years where the sugarbush was healthy at the time of the storm and damage was light to moderate, to as many as 40 years where the bush was in declining health and damage was severe. Of course favorable conditions after the storm, especially adequate precipitation and freedom from serious insect damage, will help the recovery process.

It is expected that recovery assistance programs, combined with the hard work and perseverance of the affected maple producers, will ensure that the disruption caused by the ice storm is minimized. The management guidelines developed as a result of the ice storm and the findings of applied research should contribute to the recovery of the industry and will be valuable when there is a reoccurrence of the ice storm events in the future.

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Extent of Damage in New York State and Department of Environmental Conservation's Response

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Abstract

The Department of Environmental Conservation, Division of Lands and Forests staff worked continuously to address the ice storm's impact on forest and community trees. We developed storm impact maps, coordinated with the USDA Forest Service to secure congressional relief funding, hired eight staff foresters, and passed through millions of Forest Service dollars to cooperating agencies. The division's objective was to get assistance on the ground to the people and businesses in need. It is now very evident the natural resources of northern New York suffered a great impact from the ice and subsequent snowfalls in early 1998. The extent of this impact is being determined. Protocols for evaluating the affect of future storms on natural resources should build on this experience.

Introduction

The New York State (NYS) Department of Environmental Conservation (DEC) is a large agency, employing close to 4,000 people across the state. It comprises dozens of professional fields including engineers, lawyers, personnel administrators, accountants, biologists, foresters, conservation police, forest rangers, surveyors, mechanics, land appraisers, forest and wildlife technicians, air and water quality technicians, and many more titles. It is important to recognize that the Division of Lands and Forests is a small component of this much larger agency.

The division employs just over 200 people, also scattered across the state including New York City and Long Island. Of these 200, roughly 120 are foresters and technicians. Prior to 1996, the division also included 130 forest rangers, but they were removed from the division at that time and assigned to the Office of Public Protection, along with the environmental conservation officers. When the storm hit northern New York, the division became a major player in the emergency. Four field offices were immediately impacted by electrical outages or flooding: Watertown, Potsdam, Lowville, and Raybrook. The staff at these offices spent hundreds of hours trying to protect facilities from the cold temperatures and the rising waters, even though their own homes were similarly threatened. The staff ran pumps and generators, conducted patrols of private residences, and staffed emergency shelters. The primary message for staff and the public was health and safety first.

The work did not stop once the electricity was restored or when roads and schools were reopened. Damage assessments on state forest lands, in the Forest Preserve, in communities, and on private forest lands began immediately. The extent of the impact was not truly understood until mid-February. Maple syrup producers were the most vocal and vulnerable people, because the tapping season was a mere 2 months off. Many stands were flattened and any hope of tapping in the next 10–20 years was out of the question. Recommendations from Cornell were very specific in that the producers were advised to not tap or at least tap only lightly in 1998.

Assessment

Division Director Frank Dunstan wanted to obtain a quick assessment of the acres impacted. Similarly,

the USDA Forest Service, through the Durham, NH, field office, wanted immediate damage reports from the four affected states. In New York, the task was given to the Public Lands Bureau in the Division of Lands and Forests which, in turn, handed the assignment to its Geographic Information Systems (GIS) section. This group had experience in dealing with large-scale disasters such as this. They mapped and assessed the Adirondack blowdown as well as the January floods in 1996. The ice storm presented a different set of conditions to deal with, but general protocols and organizational needs were in place.

Mr. Dunstan wanted a map and general assessment and did not want us to spend an inordinate amount of time refining the location of damaged acres. Then he wanted our program efforts directed at helping landowners, businesses, and communities. The GIS unit assembled the accompanying map within these operating guidelines (Figure 1). They first collected ice deposition data from the weather service and overlaid this information on a map of the six northern counties. At the same time, they collected data from visual reports supplied by DEC staff living in the impact zone. This information helped to further refine the ice deposition lines. Lastly, in conjunction with the Forest Service Durham field office, they flew the entire area in northern New York using a 4-mile grid to map the damage. This protocol, developed by the Forest Service and also used in the Vermont, New Hampshire, and Maine surveys, became the damage data layer for mapping the storm impact in the Northeast.

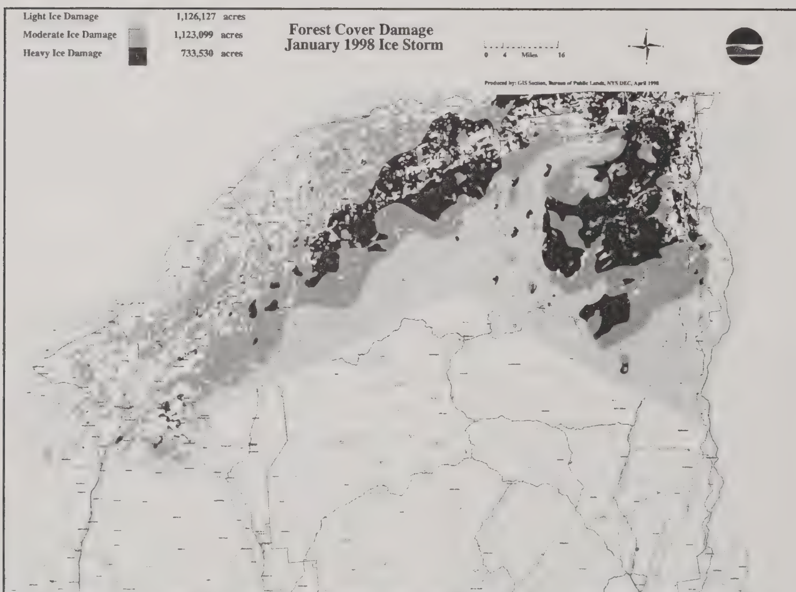

Figure 1. Forest cover damage January 1998 ice storm

New York experienced 733,530 acres of heavy damage, 1,123,099 acres of moderate damage, and 1,126,127 acres of light damage, as shown in Figure 1. These damage layers were laid over forest cover data for the state obtained from the Forest Service forest inventory records to produce this map. This is why if you look at the city of Plattsburgh and see a white area you might surmise it had no damage. Quite the contrary, it sustained heavy street tree and private property damage. Because the map was overlaid with forest cover data, Plattsburgh is automatically excluded as it is not considered a forested area. The same applies to other communities that may appear as white areas on the map. Overall, we estimated that 80 communities and "crossroads" had street trees damaged and, in many cases, fell in the heavy impact zone.

The map shows how heavy damage skirted the northern border of the NYS Forest Preserve, unlike the 1995 Adirondack blowdown, which cut right through the preserve. Trees damaged in the Forest Preserve may not be salvaged due to protection afforded in Article 14 of the State Constitution, known as the "forever wild" clause. State-owned lands classified as state forests and wildlife management lands outside the Forest Preserve blue line can be managed for forest products. The Division of Lands and Forests identified 100,000 acres of state forests and 16,000 acres of wildlife management areas in the moderate to heavy damage classes. Plans were made to remove hazardous trees and trees determined to be broken beyond their limits to survive. Health, safety, and the "wait and see" approach were paramount in our forest operations during the spring, summer, and fall. Clearing activities on the Forest Preserve lands were restricted to parking areas, state campgrounds, and hiking trails containing large amounts of tree debris.

Funding

The Forest Service State and Private Forestry office in Durham, NH, quickly realized New England and New York had been heavily damaged. They immediately began looking for assessment maps and estimates of damage from all affected states. In addition, they made plans to share these details with congressional representatives from the impacted districts. They focused on five areas of opportunity: planning and assessment, recovery and restoration, monitoring, technical assistance, and information and education. Congress was approached by the Forest Service and state representatives with a $48 million need. The Forest Service had ready-made programs to deliver the aid, if authorized, to communities, forest businesses, and forest landowners. These programs are Urban and Community Forestry, Forest Stewardship, Rural Development, Stewardship Incentive (SIP), Cooperative Forest Health Management, and Fire. These programs are delivered through Forest Service partnerships with each State Forester.

Congress and the Northeast delegation succeeded in granting funding authority for the ice storm recovery. In early May 1998, the Bosnian Aid package was passed by Congress. An attached rider provided $47,643,000 for ice storm recovery for forest lands, communities, and businesses in New York, Vermont, New Hampshire, and Maine (U.S. Department of Agriculture, Forest Service 1998). New York's share was $8,473,000. The DEC Division of Lands and Forests already had ideas on how to make best use of the funds.

Activities to Date

The commitment made by New York forestry personnel was to get the funds in the hands of needy communities, businesses, and landowners as soon as possible. The division was not able to absorb the 20 percent cost-share rate required, so it was deemed best to pass the bulk of the dollars directly to communities and organizations better equipped to handle the workload within existing program levels. The division retained enough funding to cover personnel and services like printing, travel, supplies, and equipment, plus funds to hire eight staffmembers. Fortunately, as of early January, all eight people were working with the division. These people will handle the SIP cost-share incentives workload, the urban work, the forest business grants through the Adirondack Economic Development Corporation, and will assist with damage recovery on state forests and wildlife management areas and private forest lands.

Prior to the time when new personnel came on board, it seemed as if our existing staff worked an average of 8 days a week and 30 hours a day to assist people with their forest problems! DEC time and attendance records revealed an expenditure of more than 9 staff years of work in the first 9 months following the storm. We also began to appreciate that we could not handle the situation ourselves, so we set up contracts with Cornell and the Cooperative Extension Service to conduct workshops. These sessions focused both on the rural landowners and the communities.

Our initial thrust was chain saw safety to keep people from killing or injuring themselves. Hundreds of people who never handled a saw before now owned one and used it on the weekends around their own homes or when visiting relatives to help clean up the massive amounts of trees and branches in the woods and the backyards. Community workshops were targeted at the local governments to help them understand they would do more damage to tree resources by cleaning up the streets without first understanding what really needed to be done. We are sure a good number of trees were cut down when really all they needed was pruning to recover from the storm. In many cases the Federal Emergency Management Agency funds paid for removal of trees but not pruning. The Cornell workshops were directed at the importance of having a community street tree plan, including a street tree inventory, to help recover from this storm and to help prepare for future storms.

Workshops for forest landowners and maple syrup producers concentrated on safety and patience as the keys to success. Random and indiscriminant salvage cutting could produce greater losses than the storm itself. Recommendations strongly encouraged that in most heavily damaged sugarbushes no tapping be done for the 1998 season. Forest landowners were encouraged to get a Forest Stewardship Management Plan completed for the property before they commenced with clean-up operations. They were encouraged to apply for the Stewardship Incentive Program through the Farm Service Agency and administered by the DEC. Hundreds of people have signed up for SIP, almost completely committing the $1.8 million in Federal dollars that were available.

Finally, after much negotiation and adjustment, DEC was able to convince the Adirondack Economic Development Corporation (AEDC) to apply for a Forest Service grant to assist forest businesses. The AEDC is making $80,000 available to small forest businesses for grants. One must keep in mind that it is the small forest businesses that felt the real impact of this storm event. For the larger sawmills and paper producers, wood losses were not even a blip in the world economy. One white birch user told me he can still obtain white birch logs for the wood turning business, but as soon as the boards are sawn they twist. These trees were bent by the ice and subsequent snow weight and appeared to recover and straighten but the wood was damaged in the process. This particular owner has mills in New Hampshire and Maine, too. This is a good example of a long-term impact that not many of us, let alone Congress, can comprehend or even begin to measure at this time. The AEDC has also agreed to provide technical assistance and to contract a study of the impact on raw materials and the potential for markets to handle the low-grade smaller diameter wood.

On the DEC state forests, we completed 150 timber and pulpwood sales on 2,500 acres and recovered 1.8 million board feet, 5,600 cords, and 2,000 tons of chips valued at $515,000. Our foresters and technicians believe their timber marking in damaged stands was more conservative than their efforts following the 1995 blowdown. We also learned that younger stands were hit the hardest along with stands recently thinned or partially cut. We hope to be able to establish long-term monitoring of the storm's impact to these stands and the impact of our remedial activities as well.

The division has a forest health monitoring technical advisory committee to help us track storm affects to woodlands and their plant and animal communities. This group contains members from Cornell University, the College of Environmental Science

and Forestry at Syracuse, and the State University at Plattsburgh. This technical advisory committee will guide the establishment of forest health monitoring plots and will determine the type and extent of other monitoring efforts that may be needed.

Conclusions

We are quickly learning that the long-term nature of the post-storm monitoring is going to stretch well beyond the short-term nature of the funding provided. This is one of the unique and unfortunate things about storms that tear apart natural systems. Once the electricity is back on, roads and schools are opened, and people are back in their homes, it does not mean the storm impact is over. For communities of trees, plants, and animals, it is just beginning. This is something that is hard for people to understand. An emergency appropriation by Congress to address natural catastrophes such as the ice storm cannot be spent in 6–12 months with the expectation problems will go away. Events such as this storm, tornadoes, and floods last much longer than one is willing to accept. We have to try to work with these events and government infrastructure in the future to be better able to respond to people's needs and the recovery of their immediate environment over the long haul.

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1998 Ice Damage in New York Forests: Assessment of Impact on Forest Health

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Abstract

A phoenix helix conceptual framework for addressing forest health was used for perspective to evaluate the impacts of the 1998 ice storm event to the forests of northern New York State. A random sample using 354 plots demonstrated that serious damage was restricted to a narrow band but that some branch breakage occurred at the southern most limits of the area sampled. Breakage greater than 30 percent occurred on less than 10 percent of the area. American beech, red maple, sugar maple, balsam fir, and yellow birch, the dominant tree species, exist as pure stands and mixtures with 42 other species as a complex mosaic on a diversified landscape. Conifers were less damaged than hardwoods. Medium-sized trees were more damaged than larger or smaller trees. Although some damage occurred over a wide geographic area, only a limited amount of the forest was seriously affected, and this amount was not beyond reasonable ecological expectations for maintenance of the current forest structure and mortality pattern for the whole forest.

Introduction

There are many different ways to characterize the impact of an event like the January 1998 ice storm. This report emphasizes forest health, but characterization of impact on forest health should be based on a logical conceptual framework. This report is a preliminary quantitative evaluation of the impacts of the ice storm event on the northern New York forest using the recently developed "phoenix helix" framework (Figure 1) for addressing forest health (Manion and Griffin 1998). The figure depicts diagrammatically what will be described quantitatively in the discussion section of this report.

It is assumed that interpretation of the impacts of any event on forest health will depend on the assessment procedures, the geographic position, the species composition and size, the management activities, and the ecological perspective. Management activities will not be addressed in the present report because the available data set has a limited number of managed stands. Additional sampling in 1999 should provide additional information on managed stands. If our interpretation of the impacts of the ice storm event on the forest differs from others, it is probably related to one of the five factors in our assumptions.

The long-term objective is to develop a conceptual foundation and database for addressing current and future impacts of the 1998 ice damage event to the health of New York forests. The hypothesis we are testing is that the ice storm damage is within normal expectations for a healthy forest ecosystem. Specific objectives are as follows:

1. Randomly sample the forest so that quantitative results can be expressed as proportions of the total forest rather than extremes of specific segments of the forest.
2. Quantify the species composition of the northern New York forest to better understand the resource.
3. Quantify mechanical damage based on actual counts of broken and ripped branches so percent damage can be expressed as a proportion of the branches per acre.

Figure 1. Phoenix helix conceptual forest model relating tree growth (vertical vector), tree density (horizontal vector), and time (rotational vector) to form an upward and inward spiral. Biotic and abiotic regulators, terminators, and resource recovery agents are the driving factors in the forest behind the trees.

4. Contrast the damage in relation to expected mortality rates to better evaluate the current and long-term impacts of the ice storm on the forest ecosystem.

Procedures

The initial intention was to establish 3 plots at 200 random points in northern New York. Plots (354 total) were sampled at 118 random points in 1998. The remainder will be completed in 1999. Random latitude and longitude coordinates were generated with Microsoft Excel for a region bounded by a box with south and north boundaries of 43°40′ and 45°00′ latitude and east and west boundaries of -73°20′ and -76°30′ longitude. The southern limit of sampling attempted to sample somewhat beyond the limits of where preliminary evaluations suggested damage had occurred. The random points were transferred to DeLorme Street Atlas USA version 5.0 GIS software. Points outside of New York State or in obvious lakes were deleted. Points well outside of wooded areas (as noted by green tint on the maps) were also deleted. Field maps were produced with DeLorme and TopoScout software. The random points were transferred to Garmin GPS III navigators to facilitate travel to and location of the random points in the field. Selective availability from the satellite signal affects the accuracy of the GPS units. Therefore, the specific random point was established in the field where the GPS unit first indicated that it was within 200 feet of the target point. At that point a 10 basal area factor prism plot was established. A second prism plot was established 200 feet from the first on a line at right angles to the left of the line of travel from the road to the first point. A third prism plot was established at 200 feet from the second on a line at right angles to the left from the line of travel from the first to the second prism plot.

Site variables recorded at each prism plot were latitude, longitude, elevation, aspect, slope angle, position on slope, presence of water, silvicultural activities, agricultural activities, and excavation activities. Soil variables recorded at each plot were surface characteristics, depth, texture, stoniness, and drainage class. Tree variables recorded for each tree (≥ 3.6 inches d.b.h.) on the prism plots were species, d.b.h., alive/dead, stem failure, up to four stem defects, crown class, height of crown top, height of crown bottom, number of 2-inch diameter branches (healthy, dead, broken, ripped), percent twig death in outer crown, percent foliage with defects, and cause of foliage defect. The trees were tallied into four quadrants for each plot to be able to characterize frequency of distribution for each tree species on the plot. Three subplots (radius = 5 feet) 20 feet from plot center at 0, 120, and 240 degrees bearing were sampled for trees smaller than 3.6 inches d.b.h. and other understory vegetation. Data were recorded in the field on portable data loggers and transferred to laptop computers each night. Detailed sampling procedures can be obtained from the authors. Microsoft Excel was used to analyze the data. Data analysis is still in progress; therefore, this report is preliminary and does not utilize all of the information collected. The results reported below are based on 5,779 trees from 354 prism plots and associated subplots for 118 random sample points.

Results

Tree Species in the Region

The random forest sample identified 47 species of trees (woody vegetation > 1 inch d.b.h.) in northern New York. The abundance and significance of the various species to the forest depends on how one quantifies the trees. The relative importance (Kent and Coker 1995) of the more abundant species is summarized in Figure 2. Red maple and sugar maple have the highest relative dominance; in other words, they account for the largest basal area (13 and 12 percent of the basal area, respectively). American beech and balsam fir have the greatest numbers of individuals per acre and, therefore, the highest relative density (17 and 15 percent, respectively). Red maple, sugar maple, and yellow birch have the highest relative frequencies (11, 10, and 10 percent, respectively). Relative frequency measures the distribution of these species among 2,478 subsamples (the quadrants and subplots associated with each of the prism plots). These five species account for approximately 50 percent of the relative importance, dominance, density, or frequency of the northern New York forest. This forest system is a complex mosaic composed of various mixtures and pure stands of trees on a diversified landscape.

Geographic Distribution of Branch Breakage

The most intense damage (> 20 percent branch breakage per acre) is distributed in a restricted band across the northern part of New York (Figure 3). Moderate damage (6–20 percent branch breakage per acre) occurred to the north and south of the most intense breakage. Moderately damaged plots scattered in Lewis, Hamilton, and Essex Counties suggest branch breakage occurred well beyond where one might predict damage based on indirect reconnaissance. The distribution of lightly damaged plots (1–5 percent branch breakage per acre) and undamaged plots throughout the region show isolated pockets without damage within heavily damaged areas and some damage in areas that were not generally recognized as being impacted by serious ice accumulation. It is not certain whether the 1–5 percent breakage represents ice storm damage or a general background of breakage from other causes.

Proportion of Stands with Ice Damage

Because this is a random sample of the northern New York forests, the proportion of stands associated with different amounts of branch breakage should be representative of the region (Figure 4). No branch breakage occurred on 26 percent of the total area. Less than 10 percent branch breakage occurred on 70 percent of the area. Greater than 30 percent branch breakage occurred on less than 10 percent of the area.

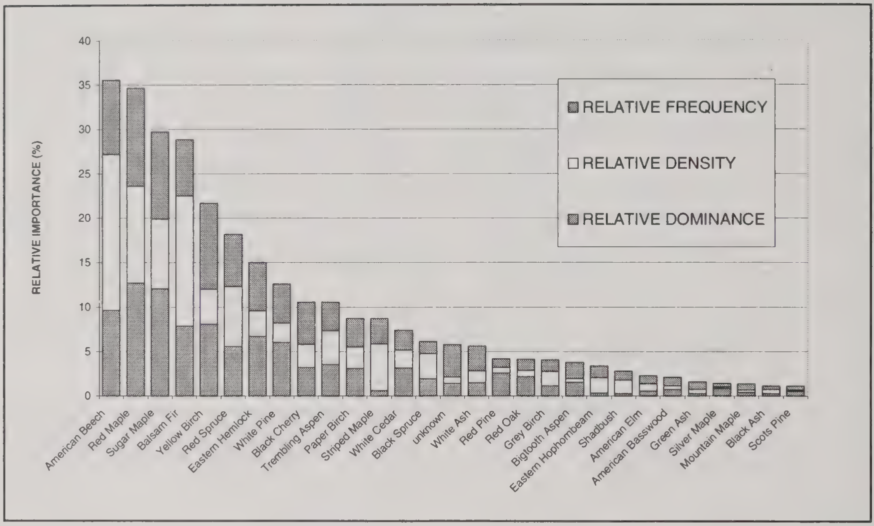

Figure 2. Relative importance (based on relative frequency, density, and dominance) of tree species within the ice damaged area of New York State

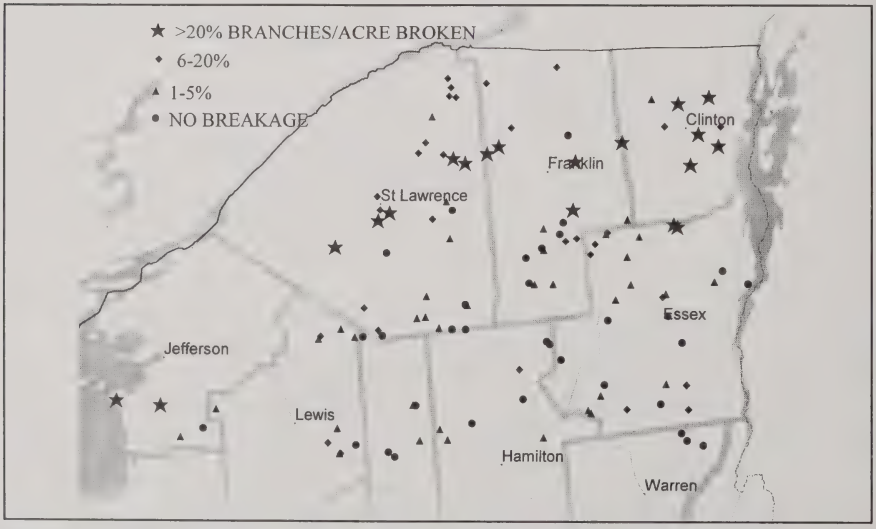

Figure 3. Distribution of random sampling sites for evaluating ice damage to trees in northern New York State

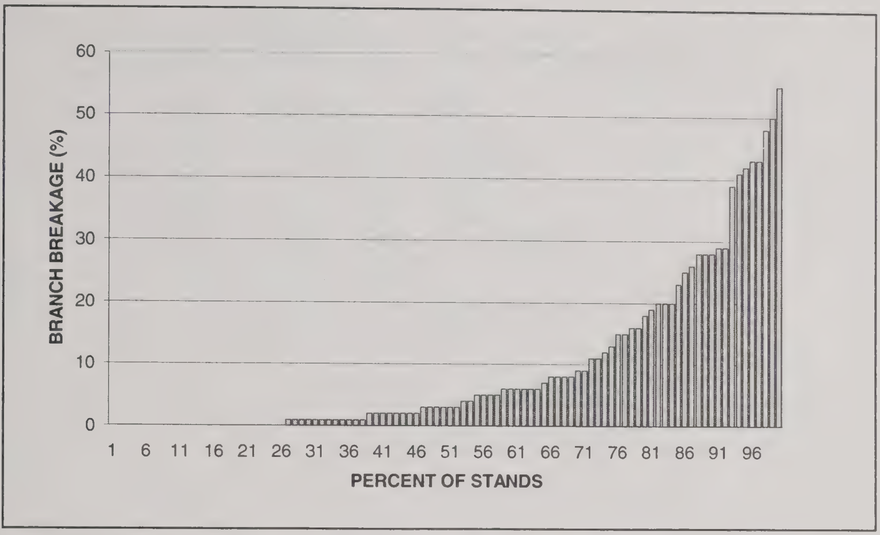

Figure 4. Proportion of forest stands with various levels of branch breakage in northern New York State

Branch Breakage by Species

Conifers received less damage than hardwoods (Figure 5). If one assumes that greater than 75 percent crown loss is a critical damage threshold, then white ash and red oak were the most seriously damaged species. If one is concerned with all levels of breakage, then trembling aspen, bigtooth aspen, and red oak were the most seriously affected trees. Among the dominant hardwoods of the region, red maple received more damage than American beech, sugar maple, or yellow birch.

Branch Breakage Within Tree Diameter Class

Serious damage (≥ 75 percent branch breakage) occurred on approximately 10 percent of the 5- to 15-inch d.b.h. classes of hardwoods (Figure 6). Serious damage occurred on 8 percent of the conifers in the 5-inch d.b.h. class and 5 percent of these trees in the 10-inch d.b.h. class (Figure 7). Some level of breakage occurred on 30 to 40 percent of all hardwoods in the 10- to 30-inch d.b.h. classes, but only on 10 to 30 percent of all conifers.

Ice Damage in Relation to Expected Mortality in the Forest

The conceptual framework for evaluating ice damage or any other forest health concern must recognize that mortality is a natural part of the forest. Biotic and abiotic regulators, terminators, and resource recovery agents are important factors in this mortality in the "forest behind the trees." The forest behind the trees is the hidden collection of trees in all diameter classes that have died during the development of the present forest. The numbers of trees in successive 1-inch diameter classes of a forest system (the survivorship curve) decreases by a quantifiable percentage. This relationship can be characterized as expected mortality associated with 1-inch of growth in a population of trees (Manion and Griffin 1998). Expected mortality provides a benchmark for evaluating impacts of specific factors (Figure 8). Predicted mortality for the northern New York forest is 25 percent for each 1-inch d.b.h. class of trees to grow 1 inch. The predicted mortality (m) is derived from the regression of the survivorship curve ($\ln N = ax + c$) with the equation $m = 1 - e^{a\Delta x}$ (Figure 8), where N is the number of trees in each

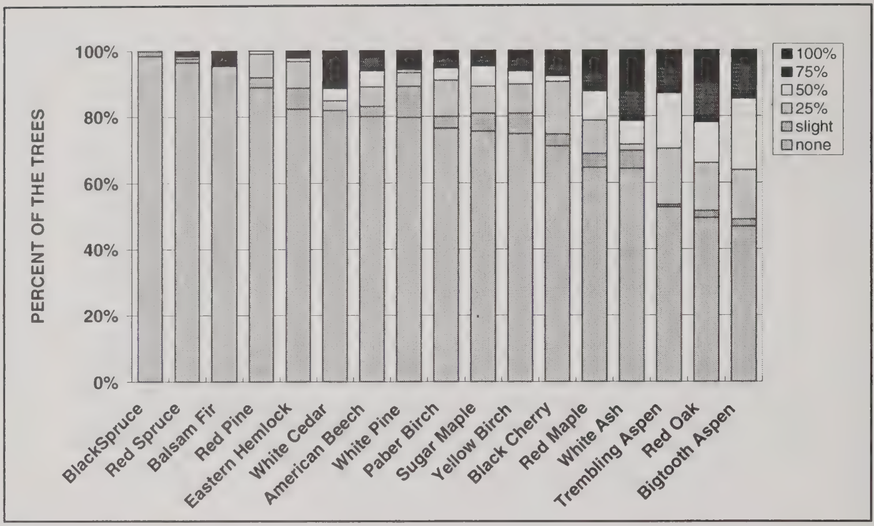

Figure 5. Relative branch breakage associated with the more abundant tree species in northern New York State

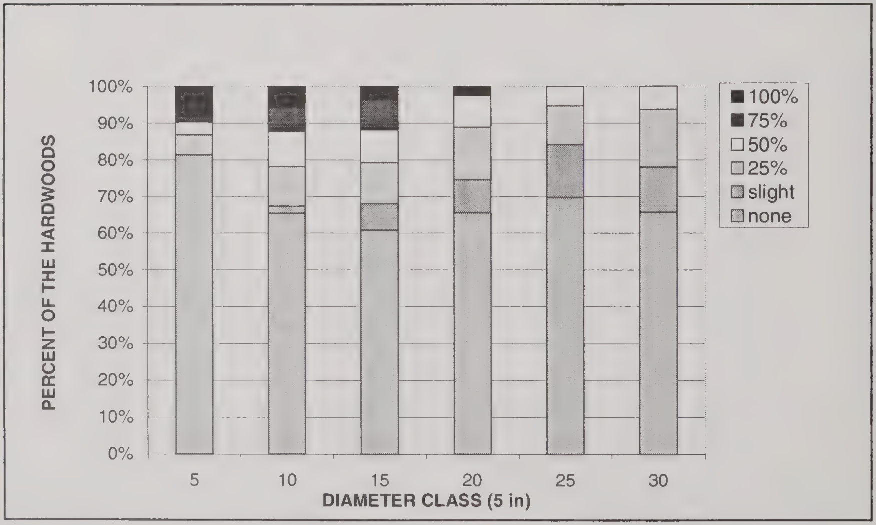

Figure 6. Relative branch breakage in each of six 5-inch diameter classes for hardwoods in northern New York State

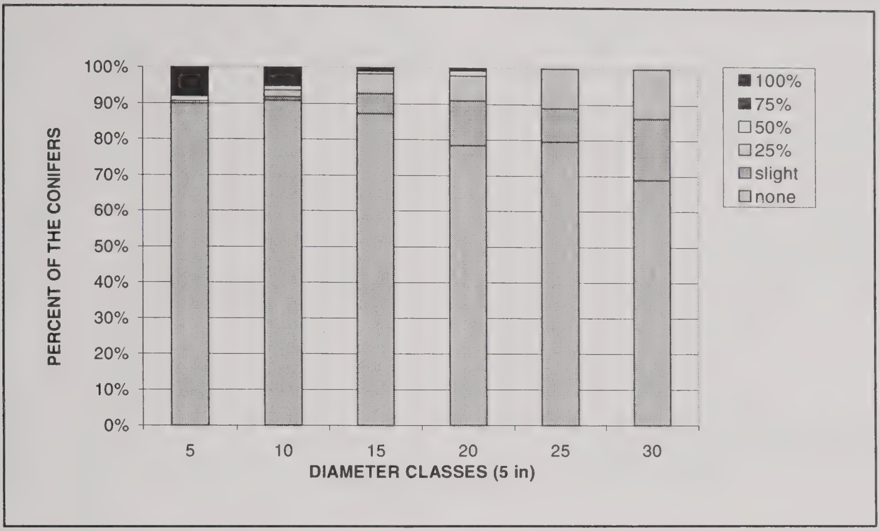

Figure 7. Relative branch breakage in each of six 5-inch diameter classes of conifers in northern New York State

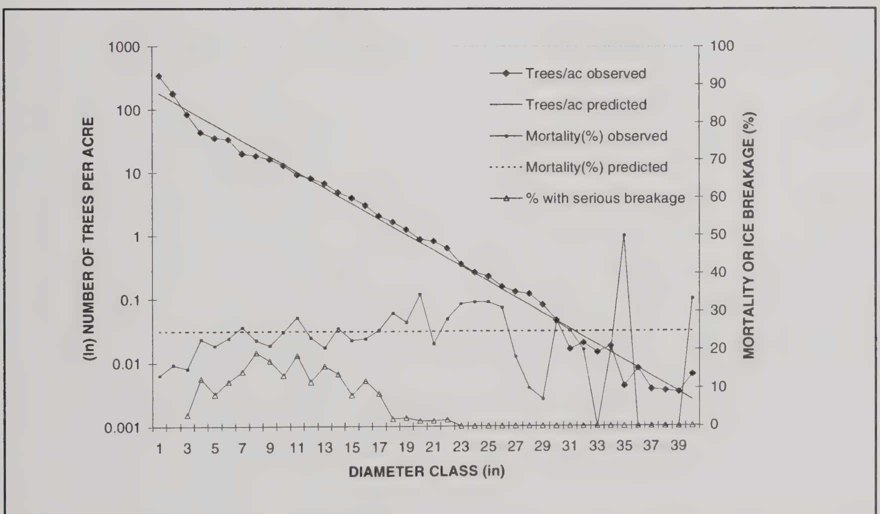

Figure 8. Percent of trees with serious (≥ 75 percent) ice induced breakage in relation to observed and predicted trees per acre and observed and predicted percent mortality across diameter classes of trees in northern New York State

diameter class of width Δx, a is the slope of the survivorship curve, e is the base of natural logarithms, and c is the intercept (numbers of trees in the 0-inch d.b.h. class). The regression of the survivorship curve fits the observed data very well, $R^2 = 0.99$.

Predicted mortality of 25 percent indicates that for the forest to maintain its present structural integrity, one out of every four trees in each 1-inch d.b.h. class will have to die for the remaining trees to grow 1 inch. The observed percent mortality in each d.b.h. class approximates the predicted mortality. The serious ice breakage percent is highest in the 4- to 17-inch diameter classes. Follow-up research will be required to determine the relationship between levels of breakage and mortality.

Discussion

What does it mean? We have minimal perspective for addressing the practical question of what the ice damage means to the health of the forest. At the College of Environmental Science and Forestry, like many colleges, we have been educating people on injury, pests, and diseases of trees, but until recently have never addressed these agents from the perspective of forest health. We need to get beyond the level of quantifying and classifying damage and into the practical question of what a specific event means to the health of the forest. The phoenix helix conceptual model provides a framework for considering impacts to forest health by addressing and quantifying mortality expected to maintain forest stability. Ice breakage and mortality are not necessarily damaging to the forest. Some of the pending long-term research on the ice damage will attempt to determine the impact of the ice damage on specific forest processes.

Simple quantification demonstrates that the ice damage was not uniform across the landscape; therefore, some areas experienced more of an impact than others. However, less than 10 percent of the forest suffered greater than 30 percent branch breakage. Some of this heavily damaged area will return to productive forest through release of advance regeneration, or through seedling and sprout regeneration, or both. Future analysis of our current data set and data from revisits to the sample sites in the future should provide some basis for understanding the factors influencing regeneration of the forest.

Damage was not equally distributed among the various tree species. Native conifers were minimally affected except in plantations. The source and composition of natural regeneration in these plantations will have to be evaluated over time.

Short-lived, early successional hardwoods, such as aspens, were more heavily damaged than longer-lived sugar maple, American beech, and yellow birch. Red maple and white ash, major components of transitional forests, were damaged more than the other long-lived hardwoods. Damage to red maple and white ash in these transition forests may allow shade tolerant advanced regeneration the opportunity to flourish, or it may allow regeneration to become established.

The distribution of damage was not uniform across diameter classes. Although bending in the sapling population was very obvious, the impact on the future forest should be minimal. Using the concept that one out of four trees in each diameter class must die for the residuals to grow an inch (phoenix helix concept), one can calculate that 68 percent of the 1-inch saplings should die before the current 1-inch cohort is 5 inches d.b.h., and likewise 90 percent of this 1-inch cohort should die before the cohort reaches 9 inches in diameter. In other words, the death of large numbers of small saplings is necessary. The resource manager may prefer that poplars and American beech die so that maples, birch, and spruce might grow. The ecological complexity of a forest system comprising more than 40 species provides a strongly buffered ecological system that can respond to an array of external and internal stimuli.

Serious breakage (≥ 75 percent) occurred on 10 percent of the 5- to 15-inch d.b.h. class of hardwoods. This breakage may lead to future mortality, but this mortality should not exceed reasonable expectations (25 percent) as discussed

earlier. Breakage in sapling to pole size classes may provide infection courts for wood decay fungi, but most of the broken branches will die and become compartmentalized before decay reaches the main stem (Manion 1991). Also, many of the damaged trees will be culled from the population as predicted by the phoenix helix concept. Ripped branches and broken tops are more serious infection courts for decay fungi that eventually lead to defects in the main stem. Evaluation of infection and subsequent impacts on the main stem will require follow-up sampling.

In summary, this preliminary analysis, based on a random representative sample, suggests that, although the 1998 ice storm event occurred over a wide geographic area, only a limited amount of forest was seriously affected. This amount was not beyond reasonable ecological expectations for maintaining the current structure and mortality pattern for the whole forest. The event was damaging to individual trees and stands, but it was not beyond normal expectations for the long-term productivity and stability of the larger population. Future analysis of subsets of the data may provide additional insight on the importance of the assessment procedures, the geographic position, the species composition and size, the management activities, and the ecological perspective on the interpretation of the impact of the 1998 ice storm event on forest health.

Acknowledgments

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Impact of the January 1998 Ice Storm on Some Maple Stands in the North American Maple Project

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Abstract

Following the January 1998 ice storm, 36 North American Maple Project (NAMP) plot-clusters located in Maine, Quebec, and Vermont had visible tree damage. Damage was usually heavier in the Quebec plots and, in general, more severe in nonsugarbush stands than in sugarbushes. The risks of crown damage and broken tops were more than 1,000 times higher for trees located in areas that received 80 millimeters of freezing rain, compared with sites subjected to 5–60 millimeters of ice. The risks of such damage also increased over 1,000 times in stands not managed for sap production compared with sugarbushes.

The risk of crown damage increased with stand elevation. The risk of light damage (1–10 percent missing crown) was greater for trees located in the medium wet sulfate deposition zone (17.6–27.5 kilograms per hectare per year [kg/ha/yr]) compared with trees at sites receiving low levels (< 17.6 kg/ha/yr) of wet sulfate deposition. Moderate to severe crown damage increased slightly with increasing nitrate deposition in nonsugarbushes only. In sugarbushes, the risks of light and moderate to severe crown damage decreased 1,000 times for trees receiving high wet nitrate deposition (> 20 kg/ha/yr) compared with trees receiving medium levels of nitrate deposition (16–20 kg/ha/yr). A similar decrease in risk of crown damage was associated with a change from the medium nitrate deposition area to an area of low deposition (< 15 kg/ha/yr). In sugarbushes, crown damage always increased with increasing basal area of sugar maple and other species and decreasing number of sugar maple stems per hectare. On the contrary, the relationships between crown damage and these two characteristics were reversed in unmanaged stands.

Similar relationships occurred between broken top damage when related to stand elevation, the basal area of sugar maple or other species, and the number of sugar maple stems per hectare. In sugarbushes, broken top damage decreased with increased nitrate deposition, but the opposite occurred in nonsugarbushes.

The risk of bearing moderate to severe crown damage was 5 times higher for red maple compared with sugar maple. Managed stands at low elevations, with larger but fewer sugar maple stems and growing with companion species such as beech, ash, or ironwood, were more resilient to the ice storm.

Introduction

The January 1998 ice storm was outstanding because of its intensity, duration, and the area covered. It was the most extensive storm of its kind in Canada since the January 1956 ice storm in the Maritime Provinces (Davidson and Newell 1957). According to surveys (Irland 1998, NEFA 1998), 64,000 square kilometers (km^2) were impacted, distributed among the northeastern states and eastern provinces: Quebec, 17,700 km^2; Ontario, 13,500 km^2; New York, 12,100 km^2; Maine, 10,100 km^2; New Brunswick, 4,000 km^2; Vermont,

3,800 km^2; and New Hampshire, 2,800 km^2. Major impacts were inflicted on humans and on regional and local utilities. Forest stands endured major damage as well.

Southeast Canada and the northeastern United States are the major areas covered by sugar maple stands. Surveys and scientific studies have been implemented following most of the major ice storms in North America during the last 65 years, but none of these studies had access to baseline data on tree condition prior to the event (Abell 1934, Downs 1938, Hepting and others 1951, Melançon and Lechowicz 1987, Whitney and Johnson 1984). The North American Maple Project (NAMP) monitors decline and recovery from decline in maple stands throughout northeastern North America and looks for differences among various levels of pollution and between sugarbushes and northern hardwood stands not managed for sap production (Allen and others 1995, Miller and others 1991). NAMP has evaluated crown and bole condition in many of the ice damaged areas since 1988. Following the ice storm, a special survey was performed in these stands in order to measure the extent of damage.

Preliminary observations and data from previous ice storms suggested that damage could vary according to aspect, stand stocking, diversity, tree species, age, size, or presence of wounds and decay (Abell 1934, Biggar 1998, Boulet 1998, Burederle and Stearns 1985, Downs 1938, Lemon 1961, Martineau and others 1973). Additionally, damage is related to weight of ice on the trees as well as stand elevation (Carvell and others 1957, Irland 1998, Rogers 1922).

The objectives of this paper are:

1. To report on the damage caused by the ice storm in stands monitored by NAMP
2. To examine differences in damage between sugarbush and nonsugarbush maple stands
3. To look for relationships between environmental, stand, or tree characteristics and the extent of damage
4. To examine nitrate and sulfate wet deposition as possible predisposing factors to damage.

Materials and Methods

Plot Network

The NAMP network spreads over 10 American states and 4 Canadian provinces and includes 233 stands each with a cluster of five 20 meter by 20 meter plots. The clusters are equally located in sugarbushes and nonsugarbush maple stands. Forty-two plot-clusters in Maine, Ontario, Quebec, and Vermont were damaged by the ice storm (Table 1). Data from Ontario (two plot-clusters) were not available. More than 4,200 trees are included in this evaluation, mainly sugar maples (2,934 trees). Other species are red maple (134 trees), yellow and white birches (183 trees), American beech (602 trees), other hardwoods including ashes, ironwood, and basswood (291 trees), and conifers (109 trees).

The amount of freezing rain (FR) received in different regions was obtained from precipitation maps published on the Internet by Environment Canada (1998). Affected plot-clusters were classified in one of the following ice deposition zones: 5–60 millimeters (FR=1) and 61–120 millimeters (FR=2). Trees in four stands from the 0 millimeter (FR=0) area in Quebec were also rated and used as controls. Time and budget constraints prohibited inclusion of other stands from the 0 millimeter area.

Three nitrate deposition zones were defined as follows: 1 (low) = 0–15 kilograms/hectare (kg/ha); 2 (medium) = 16–20 kg/ha; and 3 (high) = more than 20 kg/ha. Two sulfate deposition zones were also defined: 1 (low) = 7.6–17.5 kg/ha and 2 (medium) = 17.6–27.5 kg/ha. Plot-clusters were classified according to the nitrate and sulfate deposition zones in which they were located.

Plot-Cluster Characteristics

The following plot-cluster characteristics were obtained either from the NAMP database held at the College of Environmental Science and Forestry in Syracuse, New York, or calculated from the data collected: management category (sugarbush or nonsugarbush), elevation (meters), sugar maple basal area (square meters per hectare), basal area

Table 1. Distribution of North American Maple Project plot-clusters damaged by the January 1998 ice storm, by region and amount of freezing rain

State/province	Total clusters	Ice storm damaged clusters[1] 0 mm	5–60 mm	61–120 mm
Maine	18	0	13	0
Massachusetts	10	ns	ns	ns
Michigan	24	ns	ns	ns
Minnesota	8	ns	ns	ns
New Brunswick/Nova Scotia	14	nd	nd	nd
New Hampshire	10	nd	nd	nd
New York	27	ns	ns	ns
Ohio	6	ns	ns	ns
Ontario	24	nd	nd	2
Pennsylvania	10	ns	ns	ns
Quebec	24	4	12	4
Vermont	40	0	7	0
Wisconsin	18	ns	ns	ns
Total	233	4	32	6

[1]ns: no cluster in the storm area
nd: cluster in the storm area, but no visible damage was recorded

other species (square meters per hectare), sugar maple stocking (stems per hectare), stocking of other species (stems per hectare), and hardwood diversity (number of species).

Aspect was described by four binary variables: northern, eastern, southern, or western exposure. North encompassed bearings from 292.5° to 67.5°, east from 22.5° to 157.5°, south from 112.5° to 247.5°, and west from 202.5° to 292.5°. Flat topography scored zero.

Tree and Damage Variables

The following tree characteristics were used to describe individual trees within each plot: diameter at breast height (d.b.h.) and d.b.h.^{2}, the number of taps left open from years prior to 1998, and species.

Seven binary or ordinal damage variables were rated for each tree on each plot: tree down, bole broken below crown (BBBC), crown damage, top broken, major branches broken at bole (MBBB), wounds within the crown (WWC), and wounds below the crown (WBC) (Table 2). Crown damage was calculated as a percentage of crown lost by assessing the area of the crown with broken branches hanging on the tree or on the ground beneath the tree canopy. Plot-clusters were examined during spring 1998 before leaves developed to obtain an unobstructed view of crown and bole condition. Because of safety hazards and limited visibility, some trees could not be assessed for all damage variables.

Statistics

Logistic regressions — In order to examine the relationships between environmental factors, plot-cluster and tree characteristics, and observed damage, logistic regressions were fitted with the procedure LOGISTIC from the SAS Institute using

Table 2. **Description and values of North American Maple Project variables used to rate damage caused by the January 1998 ice storm. Assessment performed before leaf flush, in April and early May 1998.**

Variable	Ratings	Description
Tree down	0	Standing tree
	1	Fallen tree
Bole broken below crown (BBBC)	0	No damage
	1	Single bole broken below crown
	2	Multiple boles, some broken below the crown
	3	Multiple boles, all broken below the crown
Crown damage	0	0% crown broken or lost
	1	1–10% crown broken or lost
	2	11–25% crown broken or lost
	3	26–50% crown broken or lost
	4	51–75% crown broken or lost
	5	76–100% crown broken or lost
Top broken	0	No damage
	1	Single bole broken within the crown
	2	Multiple boles, some broken within the crown
	3	Multiple boles, all broken within the crown
	4	Many and only branches broken within the crown
Major branches broken at bole (MBBB)	0	No major branches broken at bole
	Count	Number of major branches broken at less than 15 cm from point of attachment on the bole
Wounds within the crown (WWC)	0	No wound with width > 20% of tree circumference
	Count	Number of wounds with width > 20% of tree circumference within the crown
Wounds below the crown (WBC)	0	No wound with width > 20% of tree circumference
	Count	Number of wounds with width > 20% of tree circumference below the crown

generalized logits and the descending option (SAS Institute 1997). Only crown damage and broken tops affected a sufficient number of trees to be examined. Because of the small number of trees in crown damage class 3 or higher, these trees were merged with class 2. For the same reason, all trees in top broken classes 1, 2, or 3 were merged in class 2. Trees in these three top broken classes suffered single or multiple bole breakage.

The initial model was as follows:

$$\begin{aligned}
\mathrm{Ln}\ [\mathrm{Freq}(D=n)/\mathrm{Freq}(D=0)] &= \mathrm{Intercept} + FR + NO_3 + (FR \times NO_3) + SO_4 + (FR \times SO_4)\\
&+ \mathrm{Region}\\
&+ \mathrm{Mgmt} + (\mathrm{Mgmt} \times FR) + (\mathrm{Mgmt} \times NO_3) + (\mathrm{Mgmt} \times SO_4)\\
&+ (\mathrm{Mgmt} \times \mathrm{Region})\\
&+ \mathrm{Elev} + (FR \times \mathrm{Elev}) + (\mathrm{Mgmt} \times \mathrm{Elev})\\
&+ Ba_{sm} + (\mathrm{Mgmt} \times Ba_{sm}) + Ba_{others} + (\mathrm{Mgmt} \times Ba_{others})\\
&+ \mathrm{Stems}_{sm} + (\mathrm{Mgmt} \times \mathrm{Stems}_{sm}) + \mathrm{Stems}_{others} + (\mathrm{Mgmt} \times \mathrm{Stems}_{others})\\
&+ \mathrm{Hrdwsp} + (\mathrm{Mgmt} \times \mathrm{Hrdwsp})\\
&+ N + (FR \times N) + E + (FR \times E) + S + (FR \times S) + W + (FR \times W)\\
&+ \mathrm{Taps}\\
&+ \mathrm{d.b.h.} + (\mathrm{Mgmt} \times \mathrm{d.b.h.}) + (\mathrm{d.b.h.} \times NO_3) + (\mathrm{d.b.h.} \times SO_4)\\
&+ \mathrm{d.b.h.}^2 + (\mathrm{Mgmt} \times \mathrm{d.b.h.}^2) + (\mathrm{d.b.h.}^2 \times NO_3) + (\mathrm{d.b.h.}^2 \times SO_4)\\
&+ \mathrm{species} + (\mathrm{species} \times NO_3) + (\mathrm{species} \times SO_4)
\end{aligned}$$

where *Ln [Freq(D=n)/Freq(D=0)]* is the natural logarithm of frequency of trees in damage class *n* divided by the frequency of trees in the no damage class; *n*=1 or 2 for crown damage and 2 or 4 for top broken. *FR* is the freezing rain area; NO_3 *and* SO_4 are the nitrate and sulfate deposition zones, respectively. *Mgmt* is the management status; *Elev*, the cluster mean elevation; Ba_{sm} and Ba_{others} the basal area of sugar maple and all other species, respectively; $Stems_{sm}$ and $Stems_{others}$ represent the number of sugar maple stems per hectare and the number of stems per hectare for all other species, respectively; *Hrdwsp*, the hardwood diversity; *N, E, S* and *W* are the four variables describing the plot aspect; *Taps*, the number of taps drilled before 1998 and still open in April 1998; *d.b.h.* and *d.b.h.*^{2} are the diameter at breast height and the square of d.b.h., respectively; and *species* indicates the tree species. Interactions are indicated as multiplications between brackets.

The LOGISTIC procedure does not handle class variables; therefore, two dummy variables (Maine and Vermont) were created to describe the regions (Kleinbaum and Kupper 1978). The default region was Quebec. Five dummy variables were also created to describe the tree species (red maple, birches, American beech, other hardwoods, and conifers). Sugar maple was the default species.

The initial models were reduced regressively by taking out the least significant variable with a probability level higher than the 0.001 threshold. No variable was taken out of the model before all the interactions within which it was associated were removed. Each initial model contained 24 independent variables, and the overall a level was 0.024 for each of the 24 variables in one test (Draper and Smith 1981) and 0.096 for the four logistic regressions, following Bonferoni's procedure (Weisberg 1985).

Logistic regression does not yield a predicted damage value for each observation, but a predicted probability that a tree is in one damage class rather than the other (Agresti 1984). As such, it is difficult to measure the impact of each significant variable on the damage levels. The odds ratios (ψ_n) measure the impact of the predictor variables and were calculated according to the following equation (SAS Institute 1997):

$$\psi_n = e^{(\delta \times \beta_n)} \qquad (2)$$

where ψ_n is the odds ratio of predictor variable *n*, *e* is a constant equal to 2.718, δ is the increase in the value of the predictor variable, and β is the parameter of this variable in the logistic regression. The odds ratio of an independent or predictor variable is a measure of the effect of a change of δ units in this predictor variable on the risk that one observation be in damage class 1 (or 2) instead of the no damage class when all other variables are kept constant (Stokes and others 1995). Wald confidence intervals for the odds ratios were calculated by the LOGISTIC procedure with an alpha level of 0.05 (SAS Institute 1997).

Logistic regression fit is rated by examining pairs of observations with different damage ratings. Concordance or discordance between the ratings and the probability of being in the higher damage class in all pairs of observations are summarized by Somer's D, a measure of association (SAS Institute 1997). Somer's D ranges from 0 (poorly fitted regression) to 1 (perfectly fitted regression).

Results

Fallen Trees

Only 12 trees (< 1 percent) of the 3,510 trees examined were uprooted. Eleven of these were located in Vermont. Because the number of fallen trees was so small, no further analysis was performed on this variable.

Bole Broken Below Crown

A majority (75 percent) of the trees with boles broken below the crown occurred in nonsugarbush stands in Maine (Table 3). Of the 161 trees in Maine with broken stems, 148 (92 percent) had multiple stems.

Crown Damage

Light crown damage (1–10 percent) occurred in 12 percent of the trees in sugarbushes impacted by the ice storm, and moderate to severe damage (11–95 percent crown breakage) occurred in 22 percent of these trees. In unmanaged stands impacted by the storm, these levels of crown damage occurred in 16 and 29 percent of the trees, respectively (Table 4). Only one tree in the control plot had crown damage.

Table 3. Number of trees with boles broken below the crown in North American Maple Project plot-clusters following the January 1998 ice storm, by management type and region

Management	Damage class[1]	Maine	Quebec	Vermont	Control[2]	Total
Sugarbush	0	599	594	113	170	1,476
	1	1	6	1	0	8
	2	3	0	2	0	5
	3	0	0	0	0	0
	Total	603	600	116	170	1,489
Nonsugarbush	0	720	700	381	158	1,959
	1	13	18	12	0	43
	2	11	3	4	0	18
	3	137	2	1	0	140
	Total	881	723	398	158	2,160

[1]0: No damage
1: Single bole broken below crown
2: Multiple boles, some broken below the crown
3: Multiple boles, all broken below the crown

[2]Number of trees in each damage class in four plot-clusters outside the area damaged by the ice storm

Table 4. Crown damage in North American Maple Project plot-clusters following the January 1998 ice storm, according to management type and region

Management	Damage class[1]	Maine	Quebec	Vermont	Control[2]	Total
Sugarbush	0	457	350	52	170	1,029
	1	80	60	20	0	160
	2	31	50	16	0	97
	3	19	69	18	0	106
	4	12	41	6	0	59
	5	4	24	3	0	31
	Total	603	594	115	170	1,482
Nonsugarbush	0	560	392	71	157	1,180
	1	77	67	143	0	287
	2	32	58	60	0	150
	3	21	81	43	0	145
	4	24	69	32	0	125
	5	29	38	39	1	107
	Total	743	705	388	158	1,994

[1]0: 0% crown broken or lost
1: 1–10% crown broken or lost
2: 11–25% crown broken or lost
3: 26–50% crown broken or lost
4: 51–75% crown broken or lost
5: 76–100% crown broken or lost

[2]Number of trees in each damage class in four plot-clusters outside the area damaged by the ice storm

The results of the logistic regression analyses are presented in Table 5 for light crown damage (1–10 percent missing crown) and in Table 6 for moderate to severe crown damage (11–99 percent missing crown). The influence of location on extent of damage—that is, whether a tree occurred in Maine rather than in Quebec or Vermont — could not be assessed, as this variable was confounded with the wet sulfate deposition zone. Management type interacted with most of the other predictor variables.

The risk of light (1–10 percent) and moderate to severe (11–100 percent) crown damage was more than 1,000 times higher both for trees located in the area receiving 80 millimeters of freezing rain compared to those in the 5–60 millimeter zone, and for trees located in the 5–60 millimeter zone compared to those in the 0 millimeter zone. The risks of such damage decreased over 1,000 times in sugarbushes compared to nonsugarbush stands.

Table 5. **Parameter estimates and probabilities of the relationship of environmental and management characteristics to presence of light (1–10 percent) crown damage compared with no damage in North American Maple Project plot-clusters impacted by the January 1998 ice storm. The logistic regression fits the data adequately, as shown by the strong association (Somer's D = 0.758) between observed light damage ratings and predicted probabilities of trees being in this light damage class.**

Variable[1]	Degrees of freedom	Parameter estimate[2]	Wald chi-square[3]	Probability
Intercept	1	-20.3755	49.27	0.0001
Freezing Rain	1	15.2056	53.66	0.0001
NO_3 Wet Deposition	1	0.6868	3.26	0.0710
SO_4 Wet Deposition	1	3.9706	34.57	0.0001
Vermont	1	1.7790	26.73	0.0001
Mgmt Type	1	-29.1876	29.67	0.0001
Mgmt × Fr	1	19.7765	29.47	0.0001
Mgmt × NO_3	1	-15.2900	65.19	0.0001
Mgmt × Vermont	1	-3.4303	46.48	0.0001
Elevation	1	0.0399	43.78	0.0001
Elevation × Fr	1	-0.0339	40.88	0.0001
Ba_{sm}	1	-0.1975	46.22	0.0001
Mgmt × Ba_{sm}	1	1.1226	67.10	0.0001
Ba_{others}	1	-0.4496	89.77	0.0001
Mgmt × Ba_{others}	1	2.3180	83.11	0.0001
$Stems_{sm}$	1	-0.0057	16.42	0.0001
$Stems_{others}$	1	0.0195	55.70	0.0001
Mgmt × $Stems_{others}$	1	-0.1121	77.43	0.0001
Hardwood Diversity	1	0.4508	14.96	0.0001
Mgmt × Hardwood Diversity	1	-1.0613	31.06	0.0001
D.b.h.	1	0.0452	65.37	0.0001

[1]Mgmt × Fr: interaction between management type and amount of freezing rain; Mgmt × NO_3: interaction between management type and amount of wet NO_3 deposition; Mgmt × Vermont: interaction between management type and location of clusters in Vermont; Elevation × Fr: interaction between elevation of plot and amount of freezing rain; Ba_{sm} and Ba_{others}: basal area of sugar maple and other species, respectively (square meters per hectare); Mgmt × Ba_{sm} and Mgmt × Ba_{others}: interactions between management type and sugar maple or other species, respectively; $Stems_{sm}$: sugar maple stocking (stems per hectare); Mgmt × Hardwood diversity: interaction between management type and cluster hardwood diversity; d.b.h.: tree diameter a breast height.

[2]Example: The parameter estimate on line 2 (freezing rain, Fr) is used in the odds ratio equation to measure the effect of a tree occurring in freezing rain area location 1 (5–60 millimeters) rather than location 0 (0 millimeters) on the risk of bearing light crown damage. By replacing the symbol β in equation 2 with the parameter estimate 15.2056, the risk of a tree having light crown damage is about 3 million times higher in the 5–60 millimeter freezing rain area compared to the 0 millimeter area (an increase of one unit in the ordinal value, from 0 to 1).

[3]The Wald chi-square is used as a significance test for each parameter in the statistical model. It is calculated as the square of the ratio of each parameter on its standard error and is compared to a chi-square distribution with one degree of freedom to assess significance.

Table 6. Parameter estimates and probabilities of the relationship of environmental and management characteristics to presence of moderate to severe (11–100 percent) crown damage compared with no damage in North American Maple Project plot-clusters impacted by the January 1998 ice storm. The logistic regression fits the data adequately, as shown by the very strong association (Somer's D = 0.903) between observed moderate to severe damage ratings and predicted probabilities of trees being in this high damage class.

Variable[1]	Degrees of freedom	Parameter estimate[2]	Wald chi-square	Probability
Intercept	1	-51.6485	182.30	0.0001
Freezing Rain	1	49.6354	207.02	0.0001
NO_3 Wet Deposition	1	3.9916	81.06	0.0001
SO_4 Wet Deposition	1	-1.5061	2.74	0.0979
Mgmt Type	1	-20.5676	97.78	0.0001
Mgmt × NO_3	1	-19.9247	207.44	0.0001
Mgmt × SO_4	1	3.7795	13.38	0.0003
Elevation	1	0.1242	181.06	0.0001
Elevation × Fr	1	-0.1160	175.91	0.0001
Ba_{sm}	1	-0.3612	116.23	0.0001
Mgmt × Ba_{sm}	1	1.2229	163.46	0.0001
Ba_{others}	1	-0.8790	183.42	0.0001
Mgmt × Ba_{others}	1	2.6872	200.82	0.0001
$Stems_{sm}$	1	-0.0170	52.95	0.0001
Mgmt × $Stems_{sm}$	1	0.0294	94.03	0.0001
$Stems_{others}$	1	0.0139	39.08	0.0001
Mgmt × $Stems_{others}$	1	-0.1148	203.79	0.0001
Hardwood Diversity	1	1.3858	77.16	0.0001
Mgmt × Hardwood Diversity	1	-1.5923	50.14	0.0001
East Aspect	1	3.9336	30.66	0.0001
East Aspect × Fr	1	-3.2548	25.47	0.0001
D.b.h.	1	0.2077	72.61	0.0001
$D.b.h.^2$	1	0.0025	44.28	0.0001
D.b.h. × SO_4	1	0.0772	34.24	0.0001
Red Maple	1	1.6229	18.10	0.0001

[1]Mgmt × NO_3: interaction between management type and amount of wet NO_3 deposition; Mgmt × SO_4: interaction between management type and amount of wet SO_4 deposition; Elevation × Fr: interaction between elevation of plot and amount of freezing rain; Ba and Ba_{others}: basal area of sugar maple and other species, respectively (square meters per hectare); Mgmt × Ba and Mgmt × Ba_{others}: interactions between management type and sugar maple or other species, respectively; $Stems_{sm}$ and $Stems_{others}$: sugar maple and other species stocking (stems per hectare), respectively; Mgmt × $Stems_{sm}$ and Mgmt × $Stems_{others}$: interaction of management type and stocking of sugar maple or other species; Mgmt × Hardwood diversity: interaction between management type and cluster hardwood diversity; d.b.h.: tree diameter at breast height; $d.b.h.^2$: square d.b.h.; d.b.h. × SO_4: interaction between tree d.b.h. and wet SO_4 deposition.

[2]Example: The parameter estimate on line 5 (management type, Mgmt) is used in the odds ratio equation to measure the effect of a tree being a sugarbush (value = 1) rather than in a nonsugarbush stand (value = 0) on the risk of having moderate to severe crown damage. By replacing the symbol β in equation 2 with the parameter estimate -20.5676, the risk for a tree having moderate to severe crown damage is more than 10^9 times lower in a sugarbush than in a nonsugarbush.

The risk of crown damage increased with stand elevation (Table 7). Moderate to severe crown damage was higher on easterly exposures protected from prevailing winds in January and February 1998. As one might expect, however, damage to these trees decreased with increasing glaze amount. Moderate to severe crown damage increased slightly with increasing nitrate deposition in nonsugarbushes only. In sugarbushes, the risks of light and moderate to severe crown damage decreased 1,000 times in the high nitrate deposition zone compared with the medium deposition zone and decreased 1,000 times in the medium compared to the low deposition zone. The risk of light crown damage was greater in the medium sulfate deposition zone than in the low deposition zone (Table 7). Moderate to severe crown damage increased 44 times in the high sulfate deposition zone in sugarbushes only.

Crown damage increased with decreasing basal area of sugar maple and other species, decreasing number of sugar maple stems per hectare, increasing number of other stems per hectare, and increasing number of hardwood species (Table 7). The risk of bearing moderate to severe crown damage was 5 times higher for red maple compared with other species, mainly sugar maple. Risk of light crown damage was 53 times higher in Vermont compared to other regions.

Table 7. Odds ratios and 5 percent confidence limits for selected environmental and management variables with presence of light (1–10 percent) or moderate to severe (11–100 percent) crown damage compared with no damage in North American Maple Project plot-clusters impacted by the January 1998 ice storm

Variable[1]	1–10% Crown damage			11–100% Crown damage		
	Odds ratio[2]	Limits		Odds ratio	Limits	
		Lower	Upper		Lower	Upper
NO_3 Wet Deposition	ns[3]	ns	ns	49.98	21.33	117.11
SO_4 Wet Deposition	53.01	14.11	199.16	ns	ns	ns
Vermont	5.92	3.02	11.63	ns	ns	ns
Elevation (10m)	1.49	1.32	1.68	3.46	2.88	4.16
East Aspect	ns	ns	ns	51.09	12.33	211.54
Ba_{sm} (2m²/ha)	0.67	0.60	0.76	0.49	0.43	0.55
Ba_{others} (2m²/ha)	0.41	0.34	0.49	0.17	0.13	0.22
$Stems_{sm}$ (50 stems/ha)	0.75	0.66	0.86	0.43	0.34	0.54
$Stems_{others}$ (50 stems/ha)	2.64	2.05	3.42	2.00	1.61	2.49
Hardwod Diversity	1.57	1.25	1.97	4.00	2.94	5.45
Red Maple	ns	ns	ns	5.07	2.40	10.70

[1]Ba_{sm} and Ba_{others}: Basal area of sugar maple and other species, respectively (square meters per hectare); $Stems_{sm}$ and $Stems_{others}$: Sugar maple and other species stocking (stems per hectare), respectively.

[2]The odds ratio of an independent variable is a measure of the increase of risk that one observation may be in damage class 1 (or 2) instead of the "no damage" class following a specified increase (usually one unit) of this independent variable, all other variables being kept constant.

[3]ns: nonsignificant

Management category interacted with many independent variables, usually reversing the impact of these characteristics in sugarbushes. Any increase in crown damage risk caused by these interactions, however, was never large enough to counteract the decrease in damage occurring in sugarbushes.

Broken Top

Broken top damage also varied between regions and management type (Table 8). The results of the logistic regression analyses are presented in Tables 9 and 10. The influence of location — that is, whether a tree was located in Maine rather than in Quebec or Vermont — could not be assessed, as the variables were confounded with the wet sulfate deposition zone. Management type interacted with most of the other predictor variables. The risk of a broken top was more than 1,000 times higher for trees in nonsugarbush stands and for trees located in the area exposed to 80 millimeters of freezing rain. There was a similar relationship between trees located in the 5–60 millimeter zone compared with those in the 0 millimeter zone. The risk of tree top breakage increased with stand elevation (Table 11). In sugarbushes, the likelihood of branch damage was more than 1,000 times higher at sites receiving medium amounts of wet sulfate compared with sites exposed to low levels of sulfate. A similar relation for nitrate deposition was associated with a 13-fold increase in the proportion of trees with broken branches and a 34-fold increase in the likelihood of broken boles. Because of the interaction between management and nitrate deposition, however, a greater than 1,000-fold decrease in the likelihood of broken boles and/or branches occurred in sugarbushes, with a change from low to medium or medium to high nitrate deposition. Risk of branch damage was lower in sugarbushes in Vermont.

As with crown damage, the proportion of broken tops decreased with increasing basal area of sugar maple and basal area of other species but increased with increasing number of stems per hectare other than sugar maple (Table 11). Management category interacted with sugar maple basal area, basal area of other species, and number of stems per hectare for other species, usually reversing the impact of these characteristics in sugarbushes. These interactions were never large enough, however, to counteract the decrease in damage occurring in sugarbushes.

Major Branches Broken at Bole

Major branch damage was present on 8 percent of the sugarbushes and 9 percent of the nonsugarbushes in Maine, 17 percent of sugarbushes and 9 percent of the nonsugarbushes in Quebec, and 14 percent of the sugarbushes and 15 percent of the nonsugarbushes in Vermont (Table 12).

Wounds Within and Below the Crown

Trees with wounds within the crown were mostly located in Quebec's sugarbushes and nonsugarbush stands, and in nonsugarbushes in Vermont (Table 13). Only 151 out of 3,474 trees suffered such damage. In total, only 23 of 3,473 trees had wounds larger than 20 percent of the tree diameter below crown (Table 13). Affected trees were mostly located in nonsugarbush stands.

D.b.h. and D.b.h.^{2}

D.b.h. and d.b.h.^{2} were significant predictor variables in three of four logistic regressions. As in any quadratic function, these two variables are correlated; however, the impact of an increase in d.b.h. on d.b.h.^{2} depends on the initial d.b.h. used to calculate the increase. Their relationships to damage are, thus, complex (Table 14). Generally, risks of damage were higher on smaller trees.

Table 8. Distribution of trees with tops broken within the crown in North American Maple Project plot-clusters following the January 1998 ice storm, by management type and region

Management	Damage class[1]	Maine	Quebec	Vermont	Control[2]	Total
Sugarbush	0	457	351	57	170	1,035
	1	13	31	3	0	47
	2	1	26	3	0	30
	3	0	2	1	0	3
	4	132	184	51	0	367
	Total	603	594	115	170	1,482
Nonsugarbush	0	572	398	186	157	1,313
	1	39	33	22	0	94
	2	10	41	7	0	58
	3	1	14	5	0	20
	4	121	218	281	1	621
	Total	743	705	388	158	1,994

[1]0: No damage
1: Single bole broken below crown
2: Multiple boles, some broken below the crown
3: Multiple boles, all broken below the crown

[2]Number of trees in each damage class in four plot-clusters outside the area damaged by the ice storm

Table 9. Parameter estimates and probabilities for the relationship between environmental and management characteristics to presence of broken branches and only branches broken within the crown compared with no damage in North American Maple Project plot-clusters impacted by the January 1998 ice storm. The logistic regression fits the data adequately, as shown by the strong association (Somer's D = 0.836) betwen broken branch damage ratings and predicted probabilities of trees occurring in this damage class.

Variable[1]	Degrees of freedom	Parameter estimate[2]	Wald chi-square	Probability
Intercept	1	-29.8266	127.48	0.0001
Freezing Rain	1	28.7808	183.27	0.0001
NO_3 Wet Deposition	1	2.5975	49.61	0.0001
SO_4 Wet Deposition	1	1.6412	4.55	0.0329
Vermont	1	0.1156	0.11	0.7438
Mgmt Type	1	-65.9557	107.36	0.0001
Mgmt × Fr	1	40.1486	89.68	0.0001
Mgmt × NO_3	1	-32.5846	146.32	0.0001
Mgmt × SO_4	1	7.8957	38.83	0.0003
Mgmt × Vermont	1	-4.8315	64.07	0.0001
Elevation	1	0.0749	138.73	0.0001
Elevation × Fr	1	-0.0673	142.28	0.0001
Mgmt × Elevation	1	0.0103	26.67	0.0001
Ba_{sm}	1	-0.4211	226.58	0.0001
Mgmt × Ba_{sm}	1	2.0618	199.12	0.0001
Ba_{others}	1	-0.7870	240.33	0.0001
Mgmt × Ba_{others}	1	4.2010	189.27	0.0001
$Stems_{sm}$	1	-0.0098	34.31	0.0001
$Stems_{others}$	1	0.0168	56.00	0.0001
Mgmt × $Stems_{others}$	1	-0.1894	185.62	0.0001
Hardwood Diversity	1	0.9419	48.77	0.0001
Mgmt × Hardwood Diversity	1	-1.9896	86.43	0.0001
D.b.h.	1	0.1780	93.28	0.0001
D.b.h.^{2}	1	-0.0015	32.37	0.0001
American Beech	1	0.8131	19.54	0.0001

[1]Mgmt × Fr; interaction between management type and amount of freezing rain; Mgmt × NO_3: interaction between management type and amount of wet NO_3 deposition; Mgmt × SO_4: interaction between management type and amount of wet SO_4 deposition; Mgmt × Vermont: interaction between management type and location of clusters in Vermont; Elevation × Fr: interaction between elevation of plot and amount of freezing rain; Mgmt × Elevation: interaction of management and elevation; Ba_{sm} and Ba_{others}: Basal area of sugar maple and other species, respectively (square meters per hectare); Mgmt × Ba_{sm} and Mgmt × Ba_{others}: interactions between management type and sugar maple or other species, respectively; $Stems_{sm}$ and $Stems_{others}$: sugar maple and other species stocking (stems per hectare), respectively; Mgmt × $Stems_{others}$: interaction of management type and stocking of other species; Mgmt × Hardwood Diversity: interaction between management type and cluster hardwood diversity; d.b.h.: tree diameter at breast height; d.b.h.^{2}: square d.b.h.

[2]Example: The parameter estimate on line 11 (elevation, El) is used in the odds ratio equation to measure the effect of tree n being located at an elevation 10 meters higher (d = 10) on the risk of having broken branches. By replacing the symbol β in equation 2 with the parameter estimate 138.73 and substituting 10 for δ in equation 2, the risk of a tree having broken branches is 2.11 times higher with an increase of 10 meters in elevation. For an increase of 100 meters ($\delta = 100$), the risk would be increased by 1,790.

Table 10. Parameter estimates and probabilities for the relationship between environmental and management characteristics to presence of single or multiple broken boles within the crown compared with no damage in North American Maple Project plot-clusters impacted by the January 1998 ice storm. The logistic regression fits the data adequately, as shown by the strong association (Somer's D = 0.884) between observed broken bole damage ratings and predicted probabilities of trees occurring in this damage class.

Variable[1]	Degrees of freedom	Parameter estimate[2]	Wald chi-square	Probability
Intercept	1	-29.9291	31.19	0.0001
Freezing Rain	1	36.1807	59.26	0.0001
NO_3 Wet Deposition	1	3.5399	60.61	0.0001
SO_4 Wet Deposition	1	-0.2878	0.09	0.7656
Mgmt Type	1	-23.0637	93.98	0.0001
Mgmt × NO_3	1	-14.1961	69.00	0.0001
Elevation	1	0.0826	39.10	0.0001
Elevation × Fr	1	-0.0793	39.34	0.0001
Ba_{sm}	1	-0.8456	147.57	0.0001
Mgmt × Ba_{sm}	1	1.3822	109.67	0.0001
Ba_{others}	1	-1.0309	147.00	0.0001
Mgmt × Ba_{others}	1	2.6811	110.49	0.0001
$Stems_{sm}$	1	-0.0042	4.65	0.0310
Mgmt × $Stems_{others}$	1	0.0116	13.84	0.0002
$Stems_{others}$	1	0.0341	79.15	0.0001
Mgmt × $Stems_{others}$	1	-0.1298	90.39	0.0001
D.b.h.	1	0.1968	29.68	0.0001
D.b.h.^{2}	1	-0.0034	28.26	0.0001
D.b.h. × SO_4	1	0.1102	22.86	0.0001

[1]Mgmt × NO_3: interaction between management type and amount of wet NO_3 deposition; Elevation × Fr: interaction between elevation of plot and amount of freezing rain; Ba_{sm} and Ba_{others}: Basal area of sugar maple and other species, respectively (square meters per hectare); Mgmt × Ba_{sm} and Mgmt × Ba_{others}: interactions between management type and sugar maple or other species, respectively; $Stems_{sm}$ and $Stems_{others}$: Sugar maple and other species stocking (stems per hectare), respectively; Mgmt × $Stems_{sm}$ and Mgmt × $Stems_{others}$: interaction of management type and stocking of sugar maple or other species; d.b.h.: tree diameter at breast height; d.b.h.^{2}: Square d.b.h.; d.b.h. × SO_4: interaction between tree d.b.h. and wet SO_4 deposition.

[2]Example: The parameter estimate on line 3 (nitrate deposition, NO_3) is used in the odds ratio equation to measure the effect of a tree being located in deposition zone 2 (medium) rather than zone 1 (low) (or high rather than medium) on the risk of bearing broken branches and bole(s). Be replacing β in equation 2 with the parameter estimate 3.5399, the risk for a tree bearing broken branches and boles is 34.5 times higher with a change from low to medium NO_3 deposition. However, from line 6 (intereaction between management type and NO_3 deposition, Mgmt × NO_3), the odds ratio equation to measure the additional impact of a sugarbush tree being located in the medium nitrate deposition zone rather than in the low deposition zone on the risk of bearing broken branches and boles decreases by more than a million times with an increase in NO_3 deposition. The overall impact of an increase in NO_3 deposition in a sugarbush is a 200,000-fold decrease in the risk of this damage.

Table 11. Odds ratios and 5 percent confidence limits for selected environmental and management variables to presence of only broken branches or broken bole damage within the crown compared with no damage in North American Maple Project plot-clusters impacted by the January 1998 ice storm

Variable[1]	Branches broken only			One or many boles broken		
	Odds ratio[2]	Limits		Odds ratio	Limits	
		Lower	Upper		Lower	Upper
NO_3 Wet Deposition	13.43	6.52	27.67	34.46	14.14	84.02
Elevation	2.11	1.62	2.75	2.28	1.75	2.97
Ba_{sm} ($2m^2$/ha)	0.43	0.39	0.48	0.18	0.14	0.24
Ba_{others} ($2m^2$/ha)	0.21	0.17	0.25	0.13	0.09	0.18
$Stems_{sm}$ (50 stems/ha)	0.61	0.52	0.72	ns[3]	ns	ns
$Stems_{others}$ (50 stems/ha)	2.32	1.86	2.88	5.50	3.78	8.02
Hardwod Diversity	2.56	1.97	3.34	ns	ns	ns
American Beech	2.56	1.57	3.23	ns	ns	ns

[1]Ba_{sm} and Ba_{others}: basal area of sugar maple and other species, respectively (square meters per hectare); $Stems_{sm}$ and $Stems_{others}$: sugar maple and other species stocking (stems per hectare), respectively.

[2]The odds ratio of an independent variable is a measure of the increase of risk that an observation be in damage class 1 (or 2) instead of the "no damage" class following a specified increase (usually one unit) of this independent variable, all other variables being kept constant.

[3]ns: nonsignificant

Table 12. Number of trees with major branches broken at less than 15 centimeters from point of attachment on the bole in North American Maple Project plot-clusters following the January 1998 ice storm, by management type and region

Management	Number of branches broken	Maine	Quebec	Vermont	Control[1]	Total number of trees
Sugarbush	0	558	509	101	170	1,338
	1	29	61	12	0	102
	2	12	19	2	0	33
	3+	4	6	0	0	10
	Total	603	595	115	170	1,483
Nonsugarbush	0	681	567	335	157	1,740
	1	43	86	34	1	164
	2	14	33	12	0	59
	3+	5	18	3	0	26
	Total	743	704	384	158	1,989

[1]Number of trees in each damage class in four plot-clusters outside the area affected by the ice storm

Table 13. Number of wounds with width larger than 20 percent of bole circumference on main stems of trees in North American Maple Project plot-clusters following the January 1998 ice storm by location, management category, and region

Location	Management	Number of wounds	Maine	Quebec	Vermont	Control[1]	Total
Within the crown	Sugarbush	0	602	563	110	170	1,445
		1	1	27	5	0	33
		2+	0	5	0	0	5
	Nonsugarbush	0	741	656	324	157	1,878
		1	2	43	38	1	84
		2+	1	6	22	0	29
Below the crown	Sugarbush	0	603	592	111	170	1,476
		1+	0	3	4	0	7
	Nonsugarbush	0	744	697	375	157	1,973
		1+	0	7	9	0	16

[1]Number of trees in each damage class in four plot-clusters outside the area affected by the ice storm

Table 14. Increase in the risk of a tree having moderate to severe (11–100 percent) crown damage rather than no crown damage, as a function of initial diameter at breast height (d.b.h.), increase in d.b.h., and increase in d.b.h.[2] Increase in risk expressed as odds ratios.[1]

D.b.h.		D.b.h.^{2}	Increase		$O.R._{d.b.h.}$	$O.R._{d.b.h.^2}$	$O.R._{combined}$
Initial (cm)	Final (cm)	final (cm^2)	D.b.h. (cm)	D.b.h.^{2} (cm^2)			
10	20	400	10	300	7.98	0.47	3.76
	30	900	20	800	63.69	0.13	8.55
	40	1,600	30	1,500	508.26	0.02	11.78
	50	2,500	40	2,400	4,056.2	0.002	9.82
20	30	900	10	500	7.98	0.28	2.28
	40	1,600	20	1,200	63.69	0.05	3.13
	50	500	30	2,100	508.26	0.005	2.61

[1]The odds ratio of an independent variable is a measure of the increase of risk that an observation be in damage class 1 (or 2) instead of the "no damage class" following a specified increase of this independent variable, all other variables being kept constant. $O.R._{d.b.h.}$: odds ratio for increase in d.b.h. alone; $O.R._{d.b.h.^2}$: odds ratio for increase in d.b.h.^{2} alone; $O.R._{combined}$: odds ratio for both increases.

Conclusions

The most useful variables to measure the impacts of the January 1998 ice storm on maple stands were crown damage and broken top. Major branches broken at the bole and wounds within or below the crown will be useful during the next decade to examine the susceptibility to cankers and decay in glaze affected plots.

Damage was generally heavier in Quebec plot-clusters, where the ice storm was most severe. Damage was distributed differently in Maine and Vermont, most likely due to local differences in the amount of freezing rain as well as contrasting forestry and sugarbush management practices. The risks of damage increased more than 1,000 times for trees located in the areas exposed to 80 millimeters of freezing rain compared with trees in areas receiving 5–60 millimeters of freezing rain. Similarly, trees exposed to 5–60 millimeters of freezing rain were more likely to have damaged crowns than trees in areas with no freezing rain.

Undoubtedly, the cause of the multiple types of crown damage observed in the NAMP plot-clusters is attributable to the amount of glaze reaching the stands. This is consistent with previously published studies (Burederle and Stearns 1985, Rogers 1922).

For the same amount of freezing rain, sugarbushes suffered less damage than nonsugarbushes, and management for sap modified the relationships between tree damage and some stand characteristics. The risk of damage increased over 1,000 times in natural stands compared with sugarbushes. This may be due, in part, to the continuous sanitation practices and selective thinning done by most sugarbush owners.

Sugarbushes at low altitudes, with larger but fewer sugar maple stems and growing with companion species such as beech, ash, or ironwood, were more resilient to the ice storm. Sugarbush owners would be well advised to favor large sugar maples and to keep some companion species in their

stands, along with the younger sugar maples typically retained to replace old declining trees.

Red maple suffered more crown damage than sugar maple, birch, other hardwoods, or conifers. Red maple is known to be relatively susceptible to this type of stress (Abell 1934, Burederle and Stearns 1985, Downs 1938, Martineau and others 1973). Beech differed from sugar maple in that its broken tops involved more branches. The small number of other tree species prohibited us from drawing a conclusion about susceptibility to damage by freezing rain.

Increase in sulfate deposition was linked to an increase in the proportion of light crown damage in all Increase in sulfate deposition was linked to an increase in the proportion of light crown damage in all stands and to an increase in moderate to severe crown damage in sugarbushes. However, this increase in risk was small compared with that related to the amount of glaze received, management status, or stand elevation. Sulfate and nitrate deposition may have been a predisposing factor to damage, but much of its effect was overshadowed by stand management in sugarbushes.

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January 1998 Ice Storm: USDA Forest Service's Response for Damage Assessment and Landowner Assistance

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Abstract

The January 1998 ice storm affected over 17 million acres of forestland in four states. The extent and severity of this event mandated a coordinated response from state and Federal forestry agencies. Early reports of forest damage quickly brought home the fact that recovery from this storm will take several years and will require an extraordinary effort and additional resources. State and Federal forestry officials immediately began to strategize recovery efforts. The recovery effort has two major components: damage assessment and landowner/community assistance. This paper will describe these efforts and outcomes to date.

Major Recovery Issues

Initial damage estimates began to frame the needs for recovery. Five major issues arose:

1. Forest damage assessment and estimating needed recovery resources—This task involved assembling estimates of damage severity, extent, and location that could be used to inform government leaders and the public on the storm's effects. In addition, this information would be used to initially define recovery needs in terms of types of technical and financial assistance.
2. Providing ice storm recovery technical assistance to resource professionals, landowners, communities, and rural natural resource driven businesses—This task involved assembling the best current information on storm damage recovery and making this information readily accessible those in need. Recommendations on silvicultural approaches to harvesting ice damaged timber, how to estimate percent live crown loss as it relates to tree survival, potential effects on hardwood quality and maple sap production, being safe in the woods, and hazard tree recognition are some examples of technical assistance and information needs.
3. Monitoring long-term forest health and sustainability—Initial steps included determining a process and beginning the data collection on the effects of this storm and the response of the region's forests.
4. Providing assistance to rural nonindustrial private forest landowners, cities, towns, communities, and small businesses in recovery and restoration from storm damage—For the most part, FEMA and state emergency management agencies do not have programs and assistance for those people who rely on woodlands and sugarbushes for a long-term source of income, nor do they offer assistance in replacing street trees.
5. Providing clear information on damage, recovery, and restoration—This is an important function of public funded forestry organizations. The task is to produce and distribute information in various accessible formats.

Recovery Approach

Existing funds available to the USDA Forest Service and state forestry agencies to help recover from natural disasters fall far short of the needs generated by the ice storm. The region's congressional delegations recognized this and, through a bipartisan effort, were able to secure a $48.4 million supplemental appropriation specifically directed to the USDA Forest Service, State and Private Forestry for ice storm recovery. This emergency appropriation was signed into law by President Clinton on May 5, 1998. Of the total allocation, Maine received $24.9 million, New Hampshire $6.4 million, Vermont $3.9 million, New York $8.7 million, and Federal agencies $4.5 million.

These funds were allocated into existing State and Private Forestry cooperative forestry assistance programs in an effort to efficiently and effectively get the funds to where they are needed. These programs are Forest Stewardship, Stewardship Incentive Program, Urban and Community Forestry, Rural Development, and Cooperative Forest Health Management. Delivery of services from these programs is accomplished through state forestry agencies.

A mission, goals, and objectives statement was developed jointly by the four state forestry agencies and the USDA Forest Service. The mission statement reads, "Lead recovery and restoration of urban and rural forests damaged by the Northern Forest Ice Storm of January 1998, and minimize the negative economic, social, and ecological impacts on the region" (U.S. Department of Agriculture, Forest Service 1998, p. C-1) This joint planning effort has led to coordinated approaches to recovery issues and delivery of services through the cooperative forestry programs, as well as enhanced information sharing.

Forest Stewardship

The Forest Stewardship Program is a major component of the forestry recovery effort. The program helps nonindustrial private landowners manage, protect, and use their forests through technical assistance. Stewardship plans are the basis for management activities. Funds are being used to help landowners get professional advice on the extent of damage to their woodlots and to develop stewardship plans for the long-term management and restoration of their forests. Landowners with existing plans were eligible for plan revisions. Funds were also used to produce educational materials and workshops for landowners and natural resource professionals, and to establish toll free numbers and web sites to share information.

Stewardship Incentive Program (SIP)

This program provides funds to pay for management activities outlined in the stewardship plans. These practices help to promote clean water, wood products, wildlife, and other values. Several SIP practices were added to respond to the ice storm, including revision of landowner stewardship plans, marking damaged trees for removal, fire hazard reduction, construction of forest access corridors, clearing access roads and recreation trails, and clearing debris from ditches, culverts, and streams. Nonindustrial landowners with less than 5,000 acres qualified for the program.

Urban and Community Forestry

Many communities were significantly impacted by the storm. The Urban and Community Forestry Program is designed to help communities manage natural resources. All of the states included a community grant program as part of their ice storm recovery. Communities could receive funds to assess damage, inventory natural resources, develop restoration plans, repair existing trees, or plant replacement trees. Professional advice was also made available to aid in restoration. Communities were encouraged to develop plans so that the right trees were planted in the right places to minimize impact on power lines and roads in future natural disasters.

Rural Development

The goal of this program is to help communities, groups, and businesses create diversified economic

activity based on forest resources. Businesses are encouraged to make innovative use of storm-damaged wood. Foresters help rural fire departments locate areas of high fire risk or impeded access.

Cooperative Forest Health Management

This program promotes practices that restore and improve forest health. The program monitors forest health to identify forests at risk from insects, diseases, pollution, and other stresses. State and Federal forestry specialists assessed storm damage from the air shortly after the storm and implemented ground survey work. The information is to help foresters determine the impact of the storm on the region's forests.

Assessment Methods

Federal and state partners including the USDA Forest Service (State and Private Forestry, and Research) and representatives from the state forestry agencies in Maine, New Hampshire, New York, and Vermont formed an Ice Storm Assessment Group in January 1998. This group developed a damage assessment work plan that includes several regional components. Standard measurements were agreed upon so that information from different survey components could be compiled into a regional assessment. During the various surveys, information was collected on site characteristics, species, tree and limb breakage, tree condition, and fire risk. State and Federal personnel measured over 2,000 forest sample sites including permanent plots and additional sites. Survey components included the following.

Aerial Surveys and Aerial Photography—Aerial surveys (making sketches on maps from the air) were completed for New York, Vermont, and New Hampshire soon after the storm. Flights were made at 1,000 to 2,000 feet. These surveys provided general information on the location, pattern, and severity of the damage. This information was used to create state and regional maps. Aerial photography has also been a part of the damage assessment. Maine acquired 2.8 million acres of photography to provide help with their assessment of damage. The Forest Service photographed selected areas in New York, Vermont, and New Hampshire to compare with some of the aerial sketchmapped information. The goal is to develop this tool to use in assessing any future natural disaster occurrence.

Regional Damage Assessment—Based on the mapped damage areas in each state, affected forests were visited and information was collected on tree species, damage type, and fire risk from fallen debris on 1/24-acre plots. The regional assessment will provide an overall picture of what effect the ice storm had on rural forests.

Sugar Maple Damage Assessment—The North American Maple Project (NAMP) is a United States and Canadian program designed in 1988 to assess and monitor the health of sugar maple. Sample sites, located in both natural forests and sugarbushes (trees maintained for maple syrup production), were measured. Measurements will be compared to extensive regional annual summer surveys. Since many commercial sugarbushes did not fall within the NAMP plot system, additional sugarbush sites are being measured to better determine the storm's effect on the maple industry.

Forest Health Monitoring (FHM)—Forest Health Monitoring sites have been in place in New England since 1990. A portion of the sites are visited every year to obtain information on tree health. All FHM plots in Vermont, New Hampshire, and Maine that were in the storm impact area were measured in 1998. The existing FHM measurement methods, plus additional ice-related measurements, were taken. In New York, scheduled to join the Forest Health Monitoring Program in 1999, the planned plot locations were identified. These locations were visited in 1998 to determine the impact of the storm on sample sites.

Forest Inventory and Analysis (FIA)—FIA has an extensive network of sample sites throughout the United States. The data from these sites provide

basic information about the forest resource in individual states. Forest surveys were recently completed in Maine, New Hampshire, and Vermont, and just a few years ago in New York. By resurveying FIA sample sites within the storm "footprint," valuable information can be collected about the storm's effect. This resurvey is being carried out by the USDA Forest Service Northeastern Research Station FIA group and the Maine Forest Service.

Vermont Hardwood Health Resurvey—This survey was begun in 1985 to assess the condition of Vermont's hardwood forests. Permanent ground sample sites were established around the state. All sites were visited this spring, before the trees leafed out, to determine if there was damage. Follow-up visits were made over the summer.

Observations

In Maine and northern New York, the damage was widespread; in New Hampshire and Vermont, it was more scattered. Rural forests, as well as stands used for maple syrup production, were impacted.

Hardwoods, including poplar, beech, birch, black cherry, maple, white ash, and oak, were affected much more by the storm than softwoods such as pine, spruce, and hemlock. This is mainly due to the way hardwood trees are shaped and how the ice built up on the branches. In heavily damaged areas, all of the trees were affected. For instance, at some sites, black cherry had broken trunks about 10–20 feet above the ground, birch were bent over, white ash were split from top to bottom, and beech had over 50 percent limb breakage. The storm left a substantial amount of woody debris on the ground.

The trees most susceptible to bending or leaning were white birch, yellow birch, and young beech. There were stands where patches of beech and birch, with intact crowns, were all bent to the ground. In areas of regeneration, with saplings 10–15 feet high, the trees were arched over in every direction. Within forest stands, trees in the understory were less affected, probably because they were protected from the ice by taller trees.

Overall, the ice storm caused a significant forest disturbance. Various size openings were created, and many trees were severely impacted. There will probably be increased dieback and reduced vigor in heavily damaged areas for the next few years. Excessive epicormic branching (clusters of small, weak branches) on larger branches and broken trunks is occurring, especially on beech, maples, and cherries. Long-term monitoring will provide a way to document the resilience of the northern forest.

The ice storm had a significant impact on the local timber resource and caused some shifts in the forest industry. Initially, many loggers worked on urban and suburban tree removal since they had the equipment and expertise. In rural areas, loggers also assisted in road clearing and found many landowners interested in having salvage operations.

Long-Term Monitoring

Long-term monitoring will provide a way to document the resilience of the northern forest. The state/Federal assessment group plans to continue cooperating in this next phase of ice storm damage assessment. Forest Service Research has initiated long-term studies to relate injury caused by the ice storm to tree growth and survival, and development of internal stain and decay in wood. The research focuses on crop trees of yellow and paper birch, sugar maple, and white ash. Study areas are located in Maine, New Hampshire, and Vermont. More than 350 of a planned 500 trees have been marked and evaluated. In addition, permanent research plots will be established in the damage areas to follow species composition, regeneration, growth, tree condition, and mortality to monitor changes in forest stands and recovery. Additional monitoring activities are being funded through each of the states.

Assessment Report

The effort to characterize the damage from the ice storm has been a cooperative regional effort. Over 20,000 trees were assessed for ice damage during the various state and Federal forest surveys. The data is currently being analyzed and a report will be published.

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The January 1998 Ice Storm

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Abstract

During the 5-day period of January 5–9, 1998, a two-phased major ice storm struck southeastern Canada, northern New England, and northern New York near the St. Lawrence Valley. This was one of the costliest events on record for power companies and residents from Quebec to northern New York. In this report we focus on the larger scale weather events in chronological order that caused the storm. We will also discuss the connections this storm had with a large-scale weather pattern that may have been enhanced by the affects of the near record-setting El Niño conditions in the Pacific Ocean.

Overall Weather Situation for the Week of January 4–9, 1998

Sunday, January 4

Early on the morning of Sunday, January 4, an arctic cold front from central Canada dropped southeast from the Canadian Plains and moved across New York State and Quebec through New England. To the north in Quebec and Ontario, temperatures were at or below 10 °F. In the St. Lawrence Valley, readings dropped from the 40's into the upper teens. To the south, across southern Pennsylvania and into the Virginias, temperatures were in the 40's and 50's. This represents a tight thermal gradient from north to south across the area, tighter than usual for this time of year.

Monday, January 5

By sunrise Monday, low pressure over Iowa had moved east-northeast into Wisconsin. Southerly winds to the east of the low pushed the previously mentioned arctic front back north as a warm front moved into southwestern New York State. Near 50+ °F temperatures spread as far north as Jamestown, while readings in the St. Lawrence Valley remained in the 20's and teens. To the south, warm and slightly moist air was blowing north and ascending up and over the cold dome of air that had settled in over the St. Lawrence Valley and Quebec the night before. Precipitation broke out in the form of snow and sleet underneath the ascending warm air across the St. Lawrence Valley and Quebec. By Monday evening temperatures aloft had warmed enough to change the snow over to sleet and freezing rain across the St. Lawrence Valley and Quebec as the air at the surface remained below freezing.

Tuesday, January 6

By sunrise Tuesday, low pressure had weakened and moved east to just northeast of Toronto. Because the low had weakened, the warm front over New York State could only make it as far north as the St. Lawrence Valley, stretching east from near Lake Ontario through northern New England. Temperatures over most of New York were in the 40's and 50's with southerly winds. In the St. Lawrence Valley readings ranged from near 35 °F around Kingston, Ontario, to 19 °F in Quebec. Precipitation was in the form of rain with pockets of freezing rain in the St. Lawrence Valley. Freezing rain was prevalent across extreme southern Quebec where temperatures remained in the upper 20's to low 30's. Important! It should be noted for future reference that just 150 miles (241 kilometers) farther north into Quebec, temperatures remained in the low single digits, relatively unaffected by the

northward push of warm air into the St. Lawrence Valley.

By Tuesday evening, the low pressure was very weak and had moved to near Watertown. The warm front ceased moving north and became stationary from Watertown eastward across New England. This means that there would be little or no modification of the cold air to the north. The first phase of the storm was ending. Schools were closed in Massena due to some light to moderate accumulations of ice.

Wednesday, January 7

On Wednesday morning pockets of very light freezing rain and snow still existed in the St. Lawrence Valley, while during the night colder temperatures slid back south again out of the deep cold reservoir in Quebec. Most of the St. Lawrence Valley was back into the low to mid 20's with low 30's near Lake Ontario. The rest of New York State had cooled from the 50's back into the 30's and low 40's. At this point the weather was relatively quiet in the St. Lawrence Valley, but the cold air over the area had been reinforced.

Meanwhile, in another part of the United States, a vigorous jet stream disturbance was moving east across Mexico from the Pacific. In response to this, strong low pressure developed near New Orleans. Southerly wind flow strengthened out of the Gulf of Mexico into the southern United States. Warmer and extremely humid air spread north into Tennessee and the Carolinas. As a result, new precipitation was breaking out as far north as Ohio, Michigan, and southern Ontario near London and Toronto. Meanwhile, to the north, the cold dome of high pressure over Quebec and Labrador was strengthening. This kept feeding cold surface air south and southwest into the St. Lawrence Valley. During Wednesday, temperatures in the St. Lawrence Valley continued to edge downward. By sunset, readings ranged from 21 °F near Montreal to near 30 °F in Watertown (generally 2 °F to 4 °F cooler than in the morning).

By Wednesday evening (around 6:00 p.m.) most of the conditions had come together for the main part of the ice storm. Down at the earth's surface, cold air was entrenched throughout southern Quebec and southeastern Ontario, and into the St. Lawrence Valley. The intensifying storm over the Mississippi Valley acted like a fuel pump, spreading increasingly warm and moist air northward from the Gulf of Mexico. Moderate to heavy rain spread north from the Gulf into southern and western New York State.

Thursday, January 8

Moderate to heavy precipitation reached the St. Lawrence Valley Wednesday night. Although surface temperatures moderated due to the warmer rain falling from above, by 9:00 a.m. Thursday readings still ranged from 27 °F at Montreal to 32 °F in Watertown. Fort Drum and Canton were 30 °F and 31 °F, respectively.

By 3:00 p.m. temperatures in the cold dome of air were slowly warming but still remained at or below freezing. Ice was accumulating rapidly. Fort Drum had risen to 32 °F. Readings at Massena in the St. Lawrence Valley climbed to 28 °F. Watertown, Kingston, and a buoy in the St. Lawrence River near the Thousand Island Bridge all reported 32 °F. Normally this might have lead to a thaw and perhaps an end to the accumulating ice. During the day, however, colder surface air from Quebec crept back south again into the St. Lawrence Valley. By 3:00 a.m. Friday morning, temperatures had cooled down 2–3 °F throughout the St. Lawrence Valley. The ice was freezing solid and still accumulating. Rain totals Thursday (through midnight) ranged from 1 inch (2.6 centimeters) in Canton to 2.3 inches (5.8 centimeters) in Watertown, but most of the rainfall reports were around 1.2–1.8 inches (3.0–4.6 centimeters). By this time ice was thick on everything exposed.

Friday, January 9

This was the last and most dangerous phase of the storm. By sunrise Friday morning, the colder surface air in the St. Lawrence Valley had been reinforced to nearly prestorm levels. Malone was down to 22 ˚F; Fort Drum was at 28 ˚F and it was still raining. Thursday night a brand new low pressure developed over southern Ohio. By sunrise Friday, the new low had tracked into south central New York State. The track of this new storm to the south of the St. Lawrence Valley ensured that the direction of surface winds in the ice coated valley would remain from east to northeast and prevent temperatures from moderating. Furthermore, the low-pressure center itself was the focus for more heavy rain. Most of the St. Lawrence Valley picked up another amazing 0.5 to 2.5 inches (1.3 to 6.4 centimeters) of rain with temperatures ranging from 28 to 32 ˚F. Along with this was a considerable amount of lightning and thunder.

The passage of this low pressure up into New England late Friday finally allowed westerly winds from the Great Lakes to spill in across the St. Lawrence Valley, and temperatures temporarily climbed above freezing.

Rainfall Totals

In New York State it so happens that some of the greatest precipitation amounts during this 5-day period were in a west-southwest to east-northeast pattern stretching across the northern third of the state. Amounts varied from roughly 2.5 to 4.0 inches (6.4 to over 10 centimeters) of water equivalent, which resulted in ice thicknesses ranging from a trace to 2.5 inches (5.7 centimeters) (Table 1).

Table 1. Ice accumulations (radial thickness) in New York State during the ice storm of January 4–9, 1998

City	Radial Thickness (Centimeters)	Notes
Ogdensburg	2.5–3.8	
Watertown	1.9–3.8	Varied greatly throughout the city
Brownville	2.5	
Adams Center	1.9–2.5	
Pamelia	1.9–2.5	
Saranac Lake	1.3–1.9+	Nearly all this data was collected from photographs during the height of the storm.
Carthage	1.9+	
Dexter	3.8	
Clayton	1.9+	
Massena	2.5–3.0	
Constable	2.5–3.0	
Malone	3.8–5.1	
N. Stockholm	4.4	
W. Potsdam	5.1+	
Potsdam	1.9–3.0	
Canton	1.9–3.0	
Mooers	1.9–3.8	
Gouverneur	3.8+	
Sackets Harbor	1.3–1.9	
Nicholville	2.5–3.8	
Star Lake	None	
Tupper Lake	None to 0.2	
DeKalb	5.1–5.7	Ice taken off a power line was the thickness of a Thermos bottle.
Edwards	5.1	Very little ice 8 kilometers south of Edwards
Brasher Falls	5.1	Conservation officer noted much more than Massena!
Lake Placid	Trace	

El Niño

Past history shows that moderate to strong El Niño events have similar signatures in the climate over North America as well as over other parts of the world. The southern branch of the jet stream (the subtropical jet) tends to stay to the south bringing above-normal rainfall to California, Texas, and Florida, along with below-normal temperatures. The northern branch of the jet stream tends to stay to the north along the U.S./Canadian border. Both branches of the westerlies will often merge over southeast Canada.

Where jet stream winds aloft merge, there tend to be areas of high pressure below at the earth's surface. This allows high pressures with shallow cold air to spread southeast across eastern Canada.

More often than not, when surface low pressure systems move into a region of confluing or merging jet streams, the low pressure weakens. This happened over New York State on Monday and Tuesday, January 5 and 6. Later in the week, the same thing happened to a very strong low pressure that developed over the northern Gulf Coast near New Orleans, moved to the northeast toward Chicago, and then to the new low that formed over the Ohio Valley on Friday. The lows were initially strong enough to pump warm moist air in aloft over the St. Lawrence Valley, which caused the freezing rain. But the lows never remained strong as they approached the northeastern United States. This disabled them from providing the surface warmth necessary for a thaw in the St. Lawrence Valley. It seems likely that the pattern of merging jet streams over the Northeast was at least an indirect (if not direct) result of the general flow across North America that resulted from the strong El Niño.

Conclusions

The January 1998 ice storm was the result of various factors, many of which were unusual in a climatological sense and necessarily timely for a stationary event like this of such duration. In New York State, the ice accumulation occurred in a swath about 60 to 70 miles (97 to 113 kilometers) wide that stretched from the east end of Lake Ontario near Watertown to Plattsburg and covered the St. Lawrence Valley, the northern foothills of the Adirondack Mountains, and extreme northern sections of the Adirondack Mountains. Within this area of icing, it appears the worst ice accumulations occurred just south of the St. Lawrence Valley over higher terrain and on the northern edge of the Adirondacks. This is also where the greatest rainfall occurred.

The unrelentless presence of cold air to the north and the resupply of that cold air into the St. Lawrence Valley was the result of cold high pressure to the north and the sustenance of that cold air mass by confluing winds aloft. The confluing pattern of the winds aloft over the northeastern United States kept the location of icing virtually stationary for nearly 5 days and inherently kept the tight latitudinal/tight temperature gradient across the area unabated for the duration of the storm. The ice accumulation was the result of two factors: total precipitation and air temperature that was slightly colder over higher terrain. Both of these factors coexisted over northern New York State and created a kind of worst case scenario for the areas south and upland of the St. Lawrence River.

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New Hampshire Ice Storm Damage Assessment and Response

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Abstract

The January 1998 ice storm encompassed 9 of the 10 counties in New Hampshire. The damage began at elevations around 458 meters (1,500 feet) in southern New Hampshire and at about 610 meters (2,000 feet) from the White Mountain National Forest north. The damage was patchy. The severity and type of damage varied by site and forest type. The total forest area affected was approximately 427,011 hectares (1,055,130 acres). The acreage affected was determined from aerial surveys, ground assessment, and GIS analysis. The severity of damage was categorized as trace/light (< 25 percent of the crown damaged), moderate (25–50 percent of the crown damaged), or heavy (> 50 percent of the crown damaged). In sapling stands the most common type of injury was bent stems. The pole size and larger trees suffered mostly from branch breakage and snapped stems. The majority of injured trees were hardwoods.

Response

The State of New Hampshire Division of Forests and Lands began assessment on state-owned forest land immediately. A 1-day strategy meeting was attended by division staff, Cooperative Extension specialists, and representatives from the USDA Forest Service, Durham, NH, field office and the White Mountain National Forest. At this meeting, groups were assigned to plan forest assessment, consult forest landowners, address urban forest and street tree damage, and advise the public. A brief assessment form was developed to help foresters and landowners determine the level of damage in a forest stand. This form was used to collect information on stand size, area damaged, type of damage, access, and fire hazard potential. Aerial surveys were conducted statewide and damage visible from the air was mapped. In cooperation with the USDA Forest Service and the three other affected states (New York, Vermont, and Maine), New Hampshire planned and conducted regional assessment surveys. Aerial surveys began January 14, 1998, and continued until the end of January. A total of 35 hours were spent flying and mapping the damage. By delaying flights until a week following the storm, after much of the ice had melted, we were able to evaluate damage more accurately as opposed to surveying forests when they were coated with ice.

Initially, a reconnaissance was made by helicopter to obtain an overview of the area affected. The helicopter was a great benefit because it could hover over an individual area long enough for observers to classify the damage. The helicopter mission was followed with an aerial survey on our routine flight lines over areas of the state where we knew ice occurred. Flight lines were 6.4 kilometers (4 miles) apart south of the White Mountain National Forest and 3.2 kilometers (2 miles) apart north of it. An aerial survey team was formed so that multiple flights could take place on good weather days and to get information on damage extent as quickly as possible.

Tree crown injury was difficult to see immediately following the storm. We were unaccustomed to doing an aerial survey over leafless trees, so it took some time before we could map confidently. Flying was conducted at low altitude and slow speed to improve accuracy. Determining the degree of damage became fairly easy because it basically fell into one of three categories: broken branches,

snapped stems, and leaning or bent stems; however, determining the severity of branch breakage was more difficult. We discovered tree injury was patchy and certain species were more resistant to damage than others. Trees with predisposing problems, as well as trees in recently thinned areas, were most susceptible. Certain species were easy to identify even without foliage, such as white birch and red oak.

The initial aerial flights conducted by the New Hampshire Division of Forests and Lands in January 1998 mapped 101,200 hectares (250,065 acres) of damage. An additional 65,750 hectares (162,468 acres) were mapped on the White Mountain National Forest.

Beginning in May, aerial survey flights were conducted again. During these "leaf on" flights, the damage was much easier to see. As a result of these summer flights, the New Hampshire aerial survey and Federal crews mapped 166,850 hectares (412,280 acres) of heavy damage and 52,718 hectares (130,265 acres) of moderate damage statewide (Figure 1). Neither the winter nor summer aerial surveys captured light damage (less than 30 percent of the crown in an individual tree missing or broken). With the help of GIS, elevation and cover type were used to determine the area where there was a high probability of scattered light damage. This area totaled approximately 207,443 hectares (512,585 acres), bringing the total area affected to 427,011 hectares (1,055,130 acres).

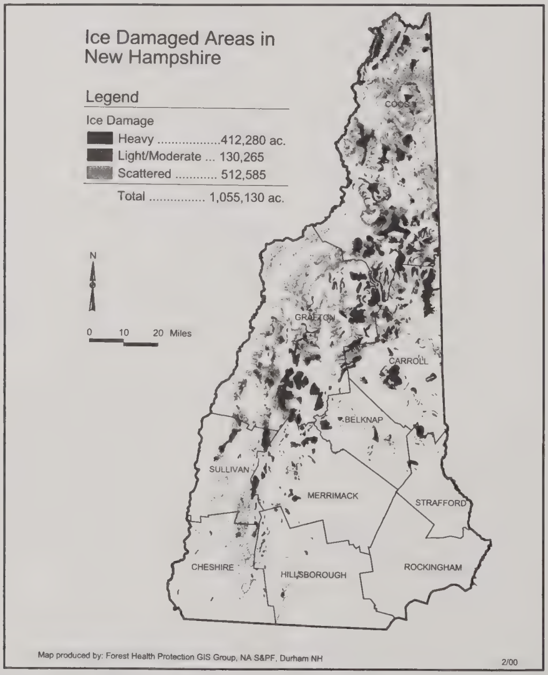

Figure 1. Forested areas in New Hampshire damaged by the January 1998 ice storm as observed during aerial surveys

During the summer, ground crews visited injured areas and compared actual ground damage with aerial survey classifications. The results of the ground survey will be published in April 1999 by the Forest Service. In general, within an individual polygon (area of damage) mapped from aerial survey, the severity of damage was not contiguous throughout. Aerial photo interpretation was done on three quarter quads (1/4 of a 7.5 minute New Hampshire quadrangle) that contained injury mapped from aerial survey. The same area of the quadrangle map was photographed from the air at a scale of 1:8,000. A comparison showed that the amount of affected area was similar using both methods (aerial survey and aerial photography). Photo interpretation, however, revealed approximately 10 percent more area affected than the aerial survey. Light damage that was not picked up while sketchmapping was detectable on photos and accounted for this difference. Although the total number of hectares damaged was very similar, the borders of the actual areas mapped were less accurate when damage from the aerial survey was overlaid onto aerial photographs.

Future Plans

Assistance has gone out to forest landowners and communities. Monitoring will continue through the Forest Health Monitoring Program, assessment monitoring, and aerial survey to track the condition of injured trees. Through the Urban and Community Forestry Program, funds will be available to communities for tree inventories, hazard tree identification, planting and restoration plans, and tree maintenance plans. Under the Stewardship Incentive Program, the state will provide advice on proper forest management and develop or revise stewardship management plans. Logger safety programs are planned that will stress safe operation in damaged stands.

Current Research

The Division of Forests and Lands, Natural Heritage Inventory will conduct a project titled "Ice Storm Damage Assessment of Rare Plant Populations and Natural Communities in New Hampshire." Nearly 500 rare plant populations and exemplary natural communities in 90 New Hampshire towns were identified by the New Hampshire Division of Forests and Lands in January 1998. Many of these lie within the White Mountain National Forest (196) or occur on state lands; several others (221) are on private lands. The effects of the storm on these rarities are unclear at this time, and we will use our biologists to determine the condition of these populations and communities, and identify necessary management actions. For example, if populations of the small whorled pogonia, a Federally endangered orchid, are buried by branches and other woody debris, do we need to work with landowners to clear the branches away? Will openings created by ice damage benefit these rare orchids, or will they allow more aggressive species to invade and thereby imperil orchid populations? Until we can get our biologists into the field, we cannot answer these critical questions for the populations of rare plant species and unusual communities.

The division is mandated by the New Hampshire Native Plant Protection Act (NH RSA 217-A: 4) to conduct investigations on rare plants and their habitats to determine population conditions and protective measures necessary for their survival. This project will also help the division meet objective 5–4 of the New Hampshire Forest Resources Plan: to monitor and track forest health in a manner that builds on existing programs and establishes baseline data across ecological conditions. The project will utilize standard New Hampshire Natural Heritage Inventory survey methods to assess rare plant and natural community conditions following the ice storm, compile and review information about each rare plant and exemplary natural communities, and conduct field surveys to identify changes to population sizes and viability that may have occurred since previous assessments. Standards will be developed to rank specifications for comparing different populations of a rare plant species (which involves both literature reviews and analyses of field data).

The Ice Storms of January 1998: Maine's Approach to Assessing the Ice Damage to its Forest Resources

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Introduction

The regional ice storms of January 7–10 and January 23–24, 1998, affected over 13 million acres of forestland in Maine. The weight of the accumulated ice caused tree branches to break and boles to break or bend over to the ground. Large branches broke within the crowns and woody debris littered the ground.

Initial Assessment of Damage

Immediately after the initial ice storm of January 7–10, the Maine Forest Service (MFS) began assessment of the storm footprint, categorizing the extent and patterns of the injury to forest stands.

Initial damage zones were based on road surveys conducted by MFS forest health specialists with additional input from local foresters. We also received calls from affected woods operators and landowners reporting damage and looking for advice.

Because of the ice and snow coverage, we did not immediately attempt to conduct aerial survey, focusing instead on the symptomology and species damaged as seen from the ground. Because of the scope of the footprint and the complex mosaic of damage patterns, we did not try to delineate every damage polygon in this first approximation of damage, instead focusing efforts on accurately delineating the general inclusion zones for various damage levels.

This initial delineation was refined by aerial survey, which began as soon as the trees shed their burden of ice. When a second ice storm occurred January 23–24, the impacts of that storm were incorporated into the overall storm footprint map (Figure 1). As this further aerial survey was conducted, we got a better look at the stands off the road, and as the trees shed their ice loads we were able to better delineate the zones of damage. We also used this opportunity to adjust zone boundaries to reflect standard Forest Health Monitoring (FHM) categories of damage, so that Maine and neighboring jurisdictions could compare data. Results from the initial mapping are listed below.

Damage class[1]	Acres (millions)
Zero-trace	4.7
Trace-light	1.6
Light	1.2
Light-moderate	1.6
Moderate	0.3
Moderate-heavy	3.6
Heavy	0.3
Total	**13.3**

[1]Trace: 1–5% breakage
Light: 6–20% breakage
Moderate: 21–50% breakage
Heavy: Over 50% breakage

These surveys served only to qualitatively delineate the storm footprint.

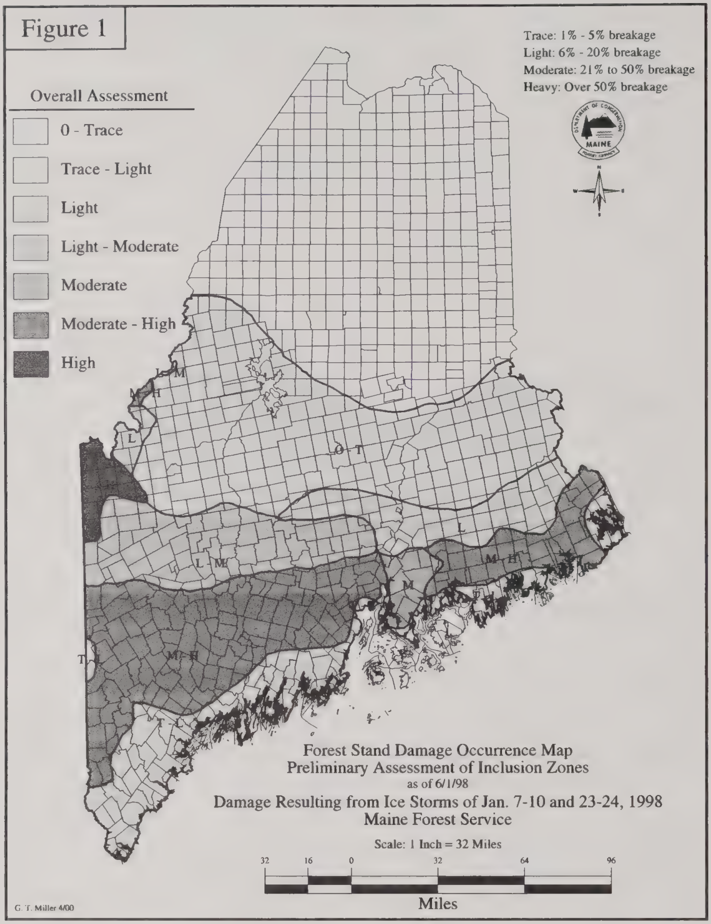

Figure 1. Forest stand damage occurrence map

Aerial Survey

To address the larger questions of quantitative levels and patterns of damage, the general storm footprint was further evaluated using an aerial strip cruise to determine the distribution of discrete damage polygons within the generally impacted zone (Figure 2). In all, a 1.2 million-acre (9 percent) subset of the damage area in Maine was surveyed using low altitude aerial sketchmapping. The damaged areas were sketched (at ~ 1:100,000 scale) and assigned to one of the four damage classifications. Stratification of the mapped results provided an assessment of distribution and pattern of damage by the various inclusion zones (Table 1a), but, except for that portion of the footprint flown, gave no indication of specific stand level damage.

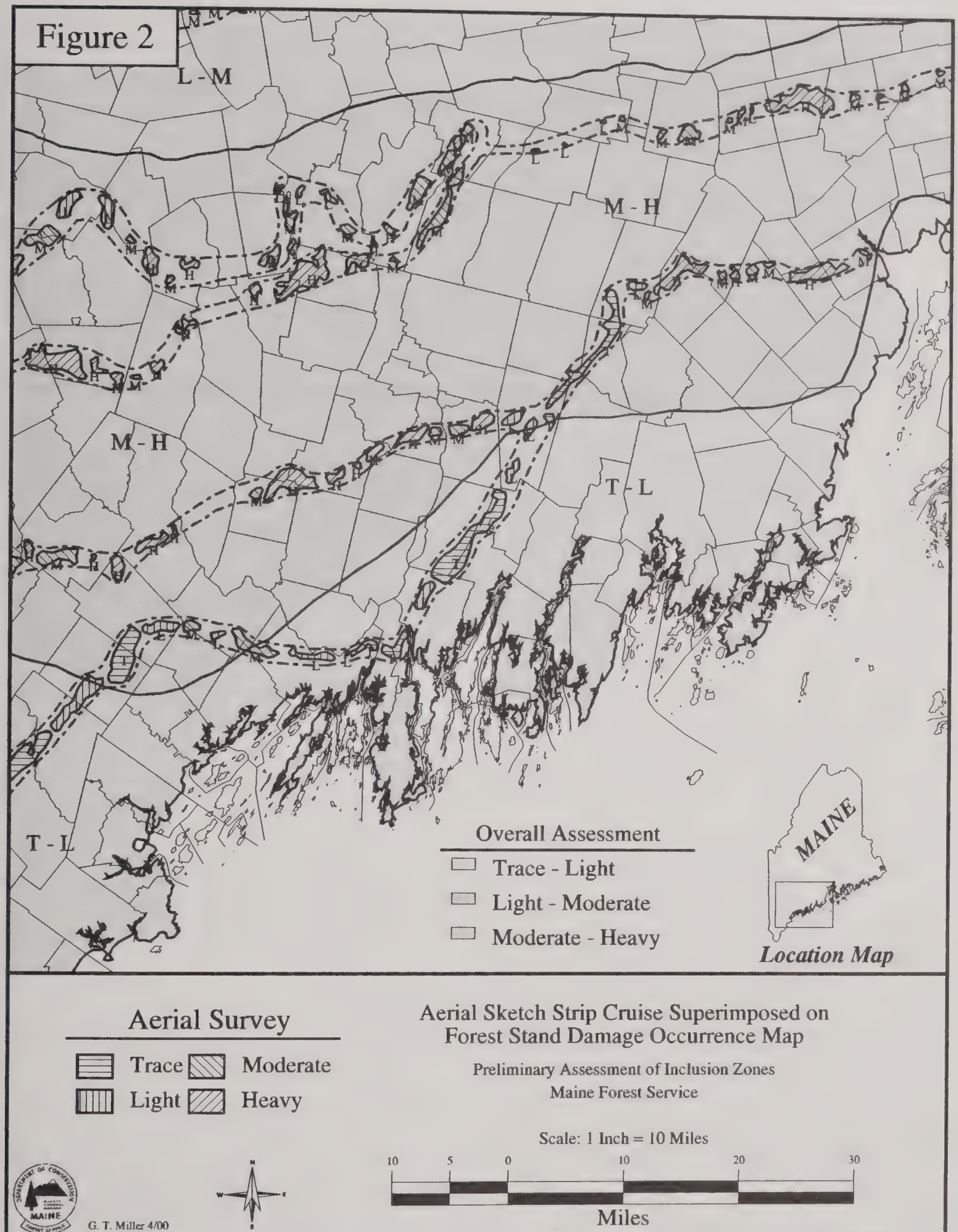

Figure 2. Aerial sketch strip cruise superimposed on forest stand damage occurrence map

Table 1. Distribution and pattern of ice-caused forest damage, by inclusion zone, Maine

a. Computed acreage of damage, by category, by zone, based on aerial sketchmapping strip cruise									
	Specific damage level								
Zone	None recorded	Trace	Light	Trace and light total	Moderate	Heavy	Moderate and heavy total	Damage zone total	Sampling intensity (percentage sampled)
Heavy	197,657	0	12,936	12,936	18,987	55,059	74,045	284,638	29.4
Mod-heavy	2,435,078	99,459	127,318	226,777	257,967	641,500	899,467	3,561,322	13.3
Moderate	199,208	0	33,166	33,166	24,884	0	24,884	257,258	10.9
Light-mod	1,472,050	0	44,611	44,611	96,478	5,067	101,545	1,618,206	8.7
Light	1,194,732	9,371	22,942	32,313	3,154	0	3,154	1,230,199	6.5
Trace-light	955,970	437,141	140,946	578,086	58,621	39,686	98,308	1,632,364	6.6
None-trace	4,661,809	0	23,157	23,157	13,368	6,380	19,748	4,704,714	5.9
Overall damage footprint	11,116,504	545,971	405,076	951,047	473,459	747,691	1,221,150	13,288,701	9.0
b. Computed acreage of damage, by category, by zone, based on photo interpretation									
Heavy	179,392	NA	36,338	36,338	58,599	10,309	68,908	284,638	83.0
Mod-heavy	2,541,704	NA	648,075	648,075	307,142	64,401	371,543	3,561,322	90.3
Moderate	204,290	NA	37,909	37,909	14,845	215	15,060	257,258	93.0
Light-mod	279,321	NA	465,014	465,014	493,277	380,594	873,871	1,618,206	5.8
Light	1,028,230	NA	158,213	158,213	39,962	3,794	43,756	1,230,199	23.7
Trace-Light	1,476,076	NA	119,740	119,740	35,740	808	36,548	1,632,364	7.7
None-trace	3,915,232	NA	684,707	684,707	104,775	0	104,775	4,704,714	0.2
Overall damage footprint	9,624,244		2,149,996	2,149,996	1,054,340	460,120	1,514,461	13,288,701	31.7

Aerial Photography

Because of the complex pattern of damage encountered, the MFS decided not to conduct wall-to-wall aerial survey, but instead to investigate potential for aerial photography and photo interpretation to capture the damage. This approach was seen as providing a higher level of spatial resolution and also an opportunity to generate hard copy products of use to individual landowners, foresters, municipalities, and their agents. After some initial experimentation, the MFS selected the following parameters:

- True color transparencies (Kodak 2448 or equivalent)
- 1:9,000 scale (750 feet per inch)
- Sidelap and endlap sufficient for stereo coverage
- Photography done before leaf-out.

This job was competitively bid and was awarded to the James W. Sewall Company of Old Town, Maine.

Because funds were initially limited and all photography was to be taken during the leaf-free period, the aerial photography was done in several phases. Initial photography was focused on the central band of damage, west of the Penobscot River. When additional funds became available, the photography was extended east to Columbia Falls. During 1998, 11,500 aerial photographs covering over 3 million acres within the moderate-heavy damage class were acquired and interpreted for forest damage.

This initial effort was extremely successful. Photo quality was high and on-ground detail easy to discern. In addition to their value as assessment tools, the photos were heavily sought after by landowners, municipalities, and foresters. In response to public and internal interest, an additional 1.1 million acres were also flown and photographed during the spring of 1999. In this process we ensured that there was some overlap between the 1998 and 1999 photos to assess the difference in detectability (as new twigs began to mask damage).

In all, over 16,000 photographs covering 4.2 million acres of Maine were photographed (Figure 3). A black and white image extracted from a sample photograph is shown in Figures 4–6, at various scales of magnification.

Photo interpretation was done by the Sewall Company using the following criteria developed by the MFS:

- Spatial resolution down to the 25-acre polygon
- Simple damage matrix
  - Crown breakage categories: < 20%, 20–50%, > 50%
  - Pattern: blanket, scattered pockets, scattered diffuse.

To assure quality of the photo interpretation, MFS forest health staff audited processes and individual map products on a fairly regular basis. Generated interpretation products were periodically made available to the MFS for field verification of interpretation validity. Much of the quality assurance effort was based on MFS staff on-ground knowledge of specific photo interpreted areas. The results from the photo interpretation, when stratified, provided a broader assessment of distribution and pattern of damage in the various inclusion zones.

Although the specific categories used in the aerial strip cruise and the photo interpretation work were not identical, and since much of the area assessed by sketchmapping did not overlap the aerial photo coverage, complete congruence of the results was not anticipated. Despite the independent nature of the two assessments, both the strip cruise sketchmapping and the aerial photo interpretation support the initial assessment of damage levels and patterns in the inclusion zones. Also, despite individual differences between the results of the two methods, the magnitude of the gross detected levels was similar (Table 1).

Figure 7 shows an example of photo interpretation for a small section of the photographed area.

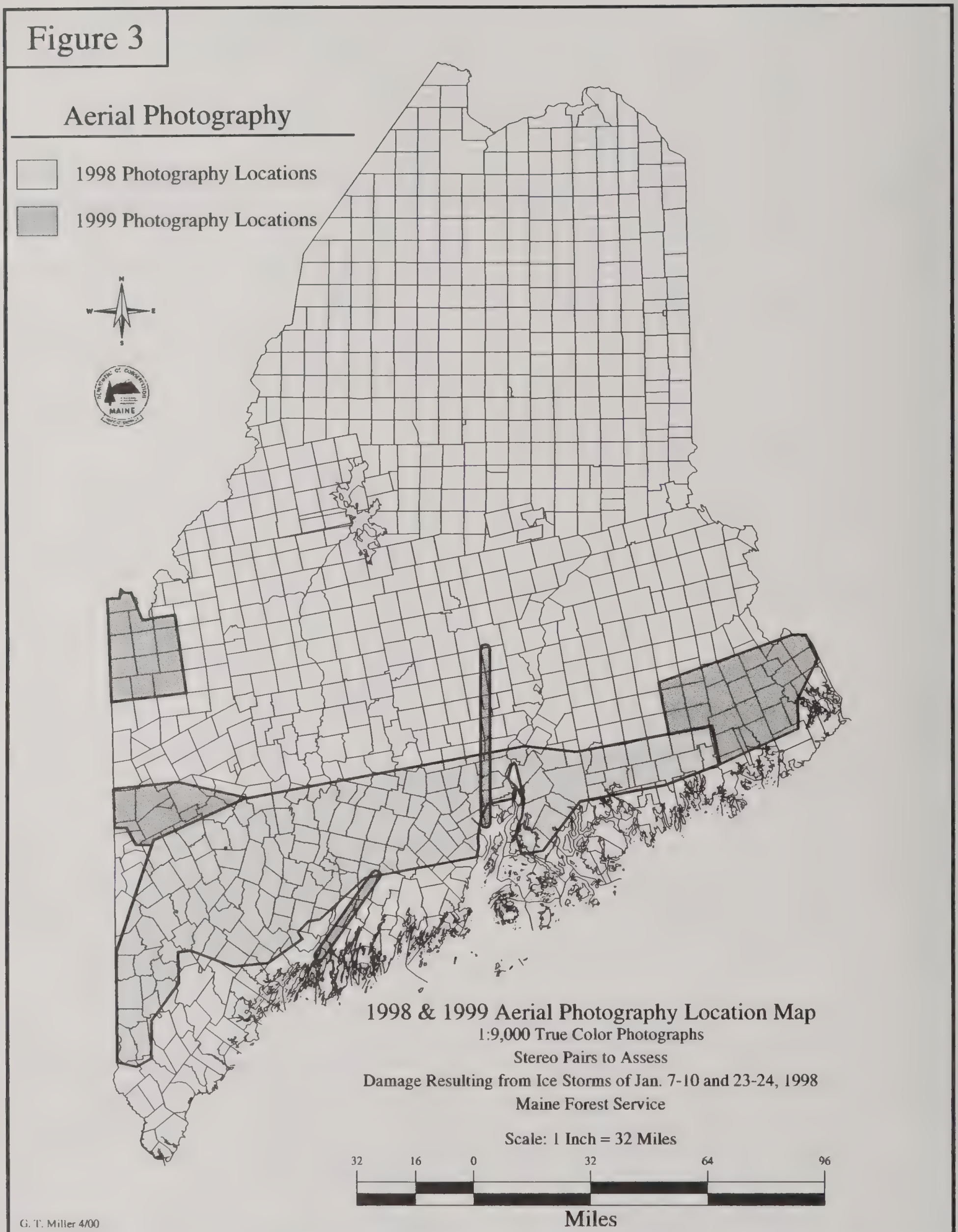

Figure 3. Aerial photography location maps, 1998 and 1999

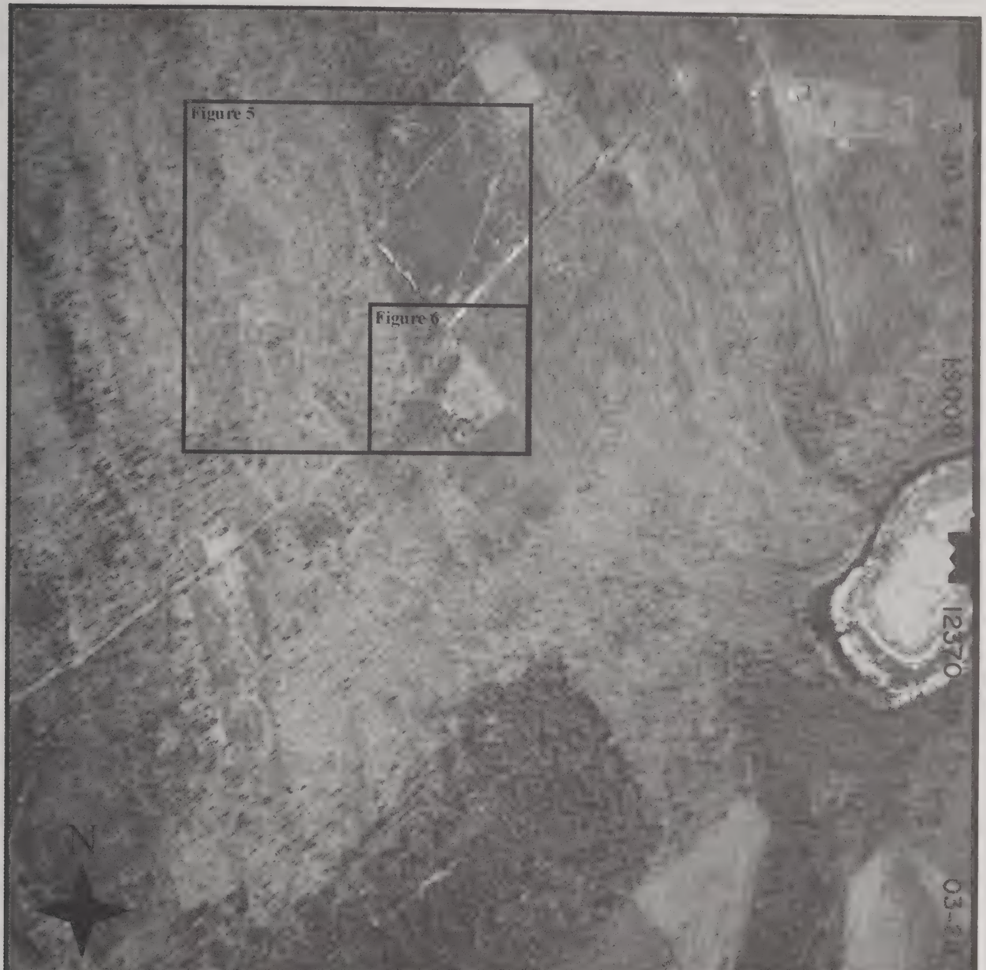

Figure 4. Aerial photograph showing damage caused by January 1998 ice storms in Liberty, ME. The boxes highlight the regions (figures 5 and 6) that show the damaged forest in greater detail. This photograph has been cropped to fit the page, but not compressed.

Figure 5. Enlargement of aerial photograph showing the damage caused by the January 1998 ice storms in greater detail (enlarged approximately 2.5 times)

Figure 6. Enlargement of aerial photograph showing the damage caused by the January 1998 ice storms in greater detail (enlarged approximately 6 times)

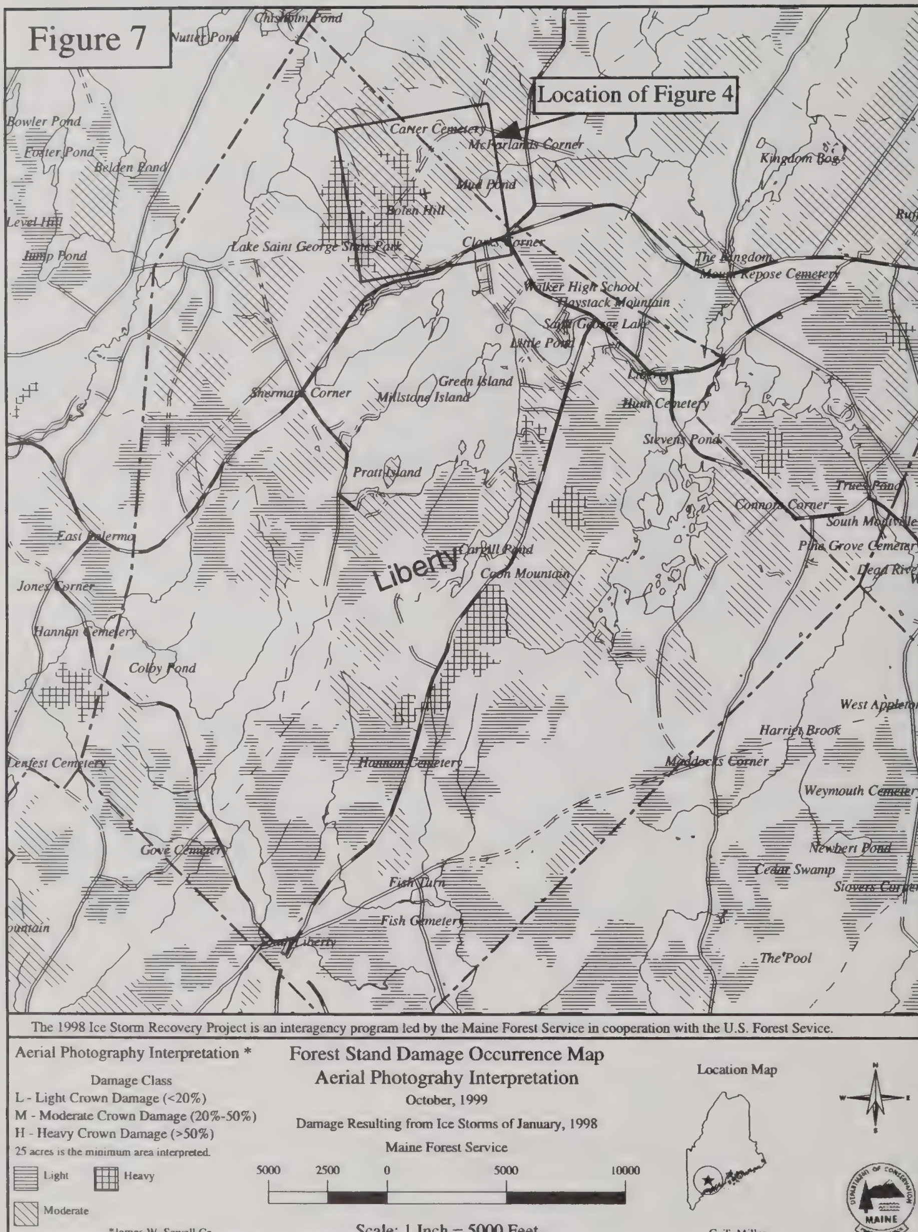

Figure 7. Photo interpretation for a small section of the photographed area

Ground Assessment

Concurrent with the aerial survey and photo interpretation efforts, MFS crews collected ground assessment data within the storm footprint from preexisting and newly established ground plots.

Ground assessment efforts centered on answering the question: How much damage is there to individual trees, and to what extent do variables such as species, aspect/elevation, stocking, existing damages, and age influence the amount of injury encountered? To address these questions and to quantify the results, the MFS engaged in a three-pronged approach.

Most of the effort was focused on collecting plot data from specific polygons generated from aerial sketchmapping and aerial photo interpretation. The methods utilized were identical to those used in New Hampshire, Vermont, and New York (i.e., a 1/24-acre circular plot—in effect a FHM subplot—on which data were collected regarding the stand, site, and the condition of the individual trees). The specific variables collected were the base FHM measurements, plus an assessment of trunk bending.

In Maine we established and measured 297 such plots across 36 sketchmapped polygons, and 150 plots across 28 photo interpreted polygons.

The results of this assessment are summarized in Table 2. In brief, they indicate the following:

- The pattern of ice damage in Maine was extremely complicated and variable. Both methods provide adequate survey results, each having different strengths and weaknesses. There was a direct relationship between the ground damage and the sketchmapped and photo generated polygon categories of light, moderate, and heavy for all hardwoods, all softwoods, and individual species.
- Crown damage levels were higher in photo generated polygons than in sketchmapped polygons for all species and all damage categories.
- Sketchmapped polygons were generally larger than photo generated polygons and contained more nontype (softwood and nonforest) and undamaged areas than photo generated polygons.
- Photo interpreters could define and place damage visible on photos very accurately.
- Sketchmappers were usually able to detect a lower level of ice damage than were the photo interpreters, especially in stands of dark bole hardwoods against dark ground cover.
- Variability of ground data (standard deviation) within polygons from both methods was high for all species and damage categories. Standard deviation was often equal to the mean for species with large numbers of trees in the survey and often exceeded the mean when tree numbers were relatively low.
- Aerial sketchmapping was a quick, accurate, and inexpensive method for initial assessment of the ice storm. Maps developed from this survey provide a basis for allocation of aerial photography and ground assessment resources.
- Aerial photo interpretation of ice damage provides a well-defined and accurately placed assessment of ice damage in a map and photo print format readily usable by landowners.

Table 2. Mean percent crown loss by damage category from aerially sketchmapped and aerial photo generated polygons for all hardwoods, all softwoods, and for tree species with more than 100 measured trees

Tree species	Mean percent crown damage by category: Light, Sketch-mapped polygon	Light, Photo polygon	Moderate, Sketch-mapped polygon	Moderate, Photo polygon	Heavy, Sketch-mapped polygon	Heavy, Photo polygon
All hardwoods	9.2	14.7	19.5	34.6	29.5	44.5
All softwoods	3.4	4.1	6.4	9.1	11.4	28.0
Red maple	7.9	14.3	19.2	41.3	31.5	48.5
White birch	8.4	13.1	22.6	25.2	27.2	40.7
American beech	9.5	17.6	18.6	38.1	31.6	49.4
White ash	5.4	16.1*	11.9	22.3	25.4	54.4
Poplar spp.	22.2*	22.3	26.5	45.8	29.1*	53.8
Red oak	5.3	11.6	17.3	28.3	21.5	35.1
White pine	7.8	3.9	13.0	11.8	14.6	34.2

*Species had less than 100 trees in either sketchmapped or photo generated polygons.

While this assessment allowed us to determine the level of damage in the identified polygons, it did not address the question of whether we were locating polygon boundaries in the proper location or whether there were damaged stands we were not detecting.

To address that question, MFS crews investigated larger areas (2,000–3,000 acres) and measured plots across the areas, regardless of where damage polygons had been identified in the area. The MFS conducted these studies in three general areas: Buckfield, Liberty, and Columbia. The approach used was to establish a series of line-plot transects across the areas. We used a mix of fixed radius plots (as described above) separated by nine 10-factor prism points on which tree species, d.b.h., crown position, and percent damage were recorded. The apportionment of the plot sample follows.

Area	FHM subplots	Prism plots	Total
Buckfield	18	164	182
Columbia	16	146	162
Liberty	13	119	132
Total	**47**	**429**	**476**

A preliminary analysis of the subset of data from Buckfield (182 plots), comparing tree condition within the sketchmapped polygons vs. photo generated polygons, indicated the following:

For sketchmapped polygons:

- Sketchmapping identified one large "heavy damage" polygon in the study area. In retrospect, an assessment area having polygons in more than one damage category is desirable. (The other intensively sampled study areas [central and eastern Maine] contain multiple damage class polygons.)

- Ground plots within the "heavy damage" polygon showed relatively uniform heavy damage. The mean damage on plots outside the sketchmapped polygon was also relatively high, but was lower than the damage noted inside the polygon. An insufficient number of "outside" points were collected during the initial survey because of limited crew availability. (Note: all "outside" plots are relatively close to the heavy damage polygon.)
- Ice damage in the Buckfield area could still be accurately measured more than 2 years after the storm. If survey resources were to become available, additional "outside" plots could be measured in 2000.
- Stands outside the sketchmapped polygons often contained considerable ice damage. These areas were usually not mapped during aerial surveys because the damaged areas were separated by lightly damaged or nonforested areas. Although sketchmapping resolution on simple damage patterns, such as gypsy moth defoliation, are often relatively precise (e.g., 25 acres), with the complex damage pattern associated with the ice storm precision generally exceeded 100 acres.

For photo generated polygons:

- Photo interpretation identified several light and moderate polygons in the study area. Also, several areas are classified as "outside" the damage threshold (25 acres is the minimum area interpreted on the air photos).
- Mean crown damage from ground plots is greater in both light and moderate polygons than damage outside these polygons (Table 2). Damage levels in the light and moderate polygons are not significantly different. This lack of difference (for Buckfield) is overshadowed by differences between light and moderate polygons seen in the large data set used for the overall analysis.
- Damage in "outside" areas is higher than expected. Many points identified as "outside" in the photo interpretation are considered "inside" the sketchmapped polygon. Damage in these areas is probably visible on the photos but is excluded due to the 25-acre minimum criterion. Much of the excluded area has a high, lightly damaged softwood component.
- A finer level of photo interpretation, perhaps a 5- or even 1-acre resolution, would increase the number of photo defined polygons.

More than 1,000 survey plots have been measured/remeasured within the ice impacted area. Although the initial use of this plot data has been to assess the accuracy of the sketchmapping and photo interpretation effort, we are moving ahead on using this ground data in conjunction with the photo interpretation's polygonal data to get a better evaluation of the ice storm's impact on Maine's forests.

Separate damage evaluation efforts assessing the condition of trees on existing plot networks were conducted cooperatively with neighboring jurisdictions. In Maine, these plot networks included North American Maple Project (NAMP), Forest Health Monitoring (FHM), and Forest Inventory and Analysis (FIA) plots. In addition, the MFS is working cooperatively with researchers at the University of Maine to evaluate the effects of ice damage on hardwoods in managed and unmanaged stands.

Existing Plot Networks

The 18 Maine NAMP plots were visited during the early spring of 1998, before leaf-out. At this time, special assessments of apparent immediate injury were conducted. Of the 18 plots, 13 had some level of damage and 4 were seriously damaged. These plots were again remeasured during the usual mid-summer period, at which time the then visible crown symptoms were recorded. The crown dieback/density/transparency values recorded at that fully foliated time were consistent with the level of injury noted in the spring. This information was forwarded to the USDA Forest Service for inclusion in the regional assessment effort.

MFS crews also revisited all FHM plots within the storm footprint during the spring of 1998. Eighty-seven plots were visited and given an initial assessment. For those plots not scheduled to be measured in 1998, no additional visit was made if no damage was noted. Plots having only light damage to a few individual trees were fully evaluated at the initial visit that time—the individual tree damage was noted, and the plots were not revisited in 1998. For those plots with significant and/or widespread damage, the initial spring assessment captured the gross overview of the situation, and the sites were revisited and remeasured during the usual summer season. In all, of the 137 FHM plots in Maine, 35 plots had at least some ice damage noted in 1998, and 18 (over 20 percent of those plots within the storm footprint) had significant damage.

As a separate look at the frequency and severity of injury, MFS crews reassessed tree condition on FIA plots within the moderate-heavy damage inclusion zones (last sampled in 1994–95). No attempt was made to revisit all plots, but we did try to get a sufficiently large sample in the central band so that we could use the results to estimate damage and impact. In all, 167 FIA plot centers were visited and damage recorded. This information has not yet been analyzed.

We intend to use the FHM and FIA plot data as an ice-impact baseline to which subsequent measurements from Maine's annualized FIA/FHM survey (started in 1999) can be compared. This will provide a de facto long-term annual monitoring plot network to look at the effect of the ice-caused injury on the inventory of forest products: degrade, growth, mortality, etc. Although the NAMP plots can not easily be incorporated into this data set, they will continue to be periodically monitored and will serve as an independent parallel evaluation.

When these state/regional evaluation plots are added to the polygonal assessment plots, the overall ice assessment effort in Maine in 1998–99 included standardized measurements from more than 1,500 plots.

Site-Specific Assessment

This effort does not begin to capture all the assessment done by landowners, consulting foresters, municipalities, and consulting arborists. Although we have no perfect way to measure the level of site-specific assessment that has been conducted, small landowners have requested more than 3,600 ice-related forest plans, and over 90 communities have requested grants for assessing the condition of their municipal shade tree resource.

We do have an independent confirmation of this level of local assessment. As anticipated, the "ice photos" were seen as attractive management aids by foresters, landowners, and municipalities. In response to public interest, the MFS provided sets of prints to the local Farm Service Agency offices and to local service foresters, and also developed a program to provide subsidized prints to qualifying individuals (landowners enrolled in ice assessment plans or the Forest Stewardship Program, municipalities, and certified consulting foresters and arborists). To date over 46,000 prints have been distributed.

The 1998 Ice Storm: Vermont Assessment and Response

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Abstract

The January 1998 ice storm damaged trees in every county in the state. Damage was mapped on 260,000 hectares (642,200 acres), or approximately 20 percent of the forest area, by special aerial surveys. Guidelines based on crown loss were developed for landowners and foresters recommending which trees to remove. Tapping guidelines for damaged sugarbushes were also developed. A survey indicated that 14 percent of sugarbushes within the area were affected. Permanent plots used to collect forest health measurements were revisited and assessed for extent of damage.

Introduction

The January 1998 ice storm was the worst ever in the experience of many Vermonters, causing severe damage to many trees and resulting in extended power outages. The initial response of the Department of Forests, Parks and Recreation was to provide personnel to help clean streets and provide emergency management needs. Following this, aerial surveys were conducted to determine extent of tree damage, and guidelines for managing damaged forest stands and sugarbushes were developed. Ground surveys were then conducted to determine the severity of damage.

Area of Ice Damage

Damage was mapped on 260,000 hectares (642,200 acres) by special aerial surveys (Figure 1). Initial surveys were conducted in January when many of the trees were encased in ice. This made damage severity very difficult to determine so additional aerial surveys were conducted for some areas after the snow had melted. The Champlain Valley received the most continuous, severe damage. Elsewhere, damage was scattered at higher elevations, generally above 1,200 meters (4,000 feet) in and near the Green Mountains. East-facing slopes tended to have the heaviest ice loading. There was little or no damage in the Taconic Mountains and the Connecticut River Valley.

Management Guidelines

Within a few weeks after the ice storm, department personnel began receiving many calls from foresters and landowners wanting to know how badly damaged a tree could be and still have a good chance of surviving or retaining economic value. Sugarmakers were asking similar questions about which trees should be tapped for maple syrup production.

Forest Management Guidelines

A search of the literature revealed very little comprehensive information on tree recovery following crown breakage. We did, however, have 10-year data on the fate of several different hardwood species with various levels of crown dieback in 1986 (Kelley and others 1997). These data showed that most overstory trees with more than 50 percent crown dieback were more likely to die than to recover within a 10-year period. Birches, particularly paper birch, were considered a higher risk because most failed to recover from dieback in excess of 25 percent.

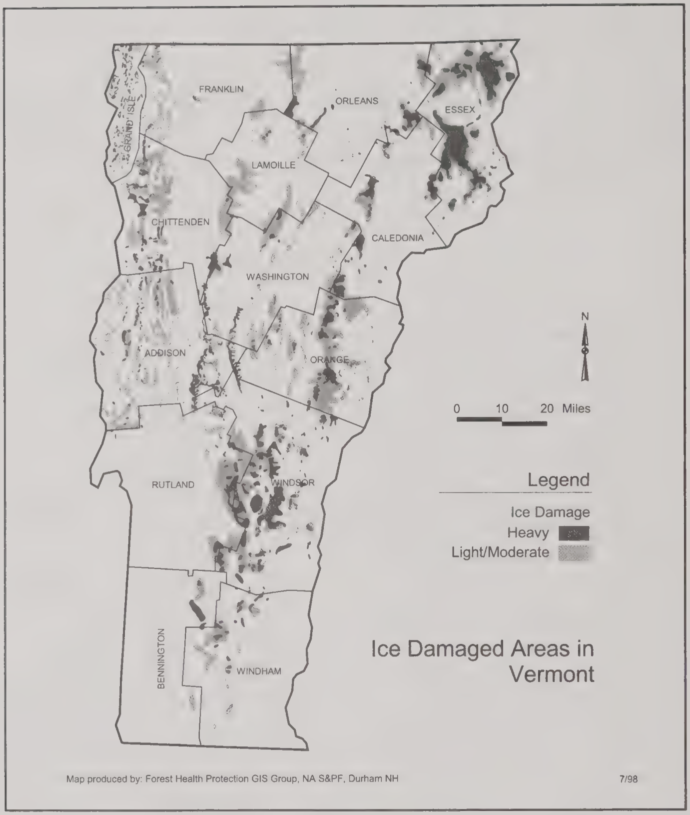

Figure 1. Damage was mapped on 260,000 hectares (642,200 acres) following the 1998 ice storm.

Ice-damaged trees went into the winter of 1997–98 in good condition, with a full complement of roots containing stored food reserves. Knowing that because of this they should respond more vigorously than trees with traditional crown dieback, estimates of likely recovery were adjusted upward one category to produce management guidelines (Table 1).

Tapping Guidelines

A management format similar to one recommended for landowners and foresters, stressing patience, safety, and the need for professional advice, was developed for operators of sugarbushes damaged by the ice storm. Tapping recommendations were based on the following four crown loss categories: (1) less than 10 percent crown loss: tap normally, (2) 11–25 percent crown loss: tap lightly, reduce number of taps, (3) 26–75 percent crown loss (trees at risk): consider all factors including desirability to retain tree in the stand, best not to tap if tree is retained, and (4) greater than 76 percent crown loss (poor chance of tree survival): tap now and plan to salvage at a later date.

Table 1. Advice for landowners and foresters managing stands damaged by the January 1998 ice storm

The Vermont Department of Forests, Parks and Recreation developed the following guidelines for forest stands damaged by the recent ice storm. They are based on 10-year crown dieback data from the Vermont Hardwood Tree Health Survey, a research review by USDA Forest Service researchers, and information on tree response to heavy pruning. These guidelines are tempered by the knowledge that in most cases, tree root systems were not injured and have good reserves of food for spring growth.

First and foremost, **don't panic** – stop, think, and be patient. Trees went into dormancy in very good health and have excellent recovery potential. **Landowners have at least the upcoming growing season to fully assess damage and determine the need for salvage.**

Recommendations based on tree species and type of damage[1]

If species is:	And crown loss is:	Recommendation is:
Red or sugar maple, beech	11–50 percent	Can retain or thin to leave best trees
Oak, cottonwood, poplar, ash, conifers, others not listed	51–75 percent	Trees at risk—can retain these for now, but reevaluate within 5 years
	> 75 percent	Remove hardwoods within 5 years
		Remove conifers with broken main stems within 1 year
Paper birch	11–25 percent	Can retain or thin to leave best trees
Yellow birch	26–50 percent	Trees at risk—can retain these for now, but reevaluate within 5 years
	> 50 percent	Remove within 5 years
If tree (any species) is: Uprooted or on the ground		Salvage within 1 year

Safety First and Foremost—Clearing access roads and evaluating forest stands containing hanging limbs and bent trees is dangerous. Use safety precuations at all times.

Get Professional Advice—Landowners should seek advice from a professional forester. Each stand is different. Site quality and other factors must be considered when applying these recommendations. Call your County Forester for details! **Trees with up to 10 percent crown loss can be managed normally**.

These Are Guidelines Only—They are based on data for upper canopy trees. Young trees tend to be even more resilient. Every site and every tree is different. Standard silvicultural considerations such as spacing, bole condition, presence or absence of suitable replacement trees, and site quality must be kept in mind when evaluating trees.

[1]Internal staining and decay may eventually cause a loss of value in damaged trees. The rate of infection will vary with species and degree of damage, but this is a very slow process. Broken main stems or stem forks are the most serious. Discoloration may progress down a tree at a rate of a few inches per year to a foot or more per year with this type of damage. Large broken branches that have torn the tree's bark are also serious. Infection associated with broken branches should remain mostly within branch wood. This is especially true for otherwise healthy sugar maples.

Sugarbush Damage

A questionnaire survey was mailed to 2,500 sugarmakers seeking information on ice storm damage to sugarbushes. Based on a 26 percent response, 14 percent said their sugarbush was damaged by the storm. Of these, 25 percent said the damage was heavy, 31 percent said it was moderate, and 44 percent said it was light. Based on this questionnaire, an estimated 75,000 taps were lost.

Damage to Monitoring Plots

The department maintains 165 permanent monitoring plots that are visited annually or periodically to collect forest health data, including crown evaluations for dieback and transparency. These include 40 North American Maple Project (NAMP) plots equally divided between sugarbushes and sugar maple stands, 22 National Forest Health Monitoring (FHM) plots, 19 Vermont Forest Ecosystem Monitoring (VForEM) plots, and 84 Vermont Hardwood Health Survey (VHHS) plots. All plots that were within the footprint of the ice storm as indicated by the aerial survey map (Figure 1) were visited in the summer of 1998 and evaluated for ice damage. In addition, all of the other tree and plot information that is taken when these plots are normally visited was collected.

Plot visits revealed that 7 NAMP plots, 6 VForEM plots, and 17 VHHS plots (18 percent of all plots) were damaged by the ice storm. In addition, the USDA Forest Service maintains about 950 Forest Inventory Analysis (FIA) plots in the state which were last visited in 1996 and 1997. Their crews revisited 126 plots that fell within the ice storm footprint and collected data on the 116 plots (12 percent of all FIA plots) that received damage.

Severity of Damage

Information on tree damage in these plots is currently being analyzed. As one might expect, damage ranged from very light to severe, depending on plot location. In general, pole size trees suffered the most bole breakage, while saplings tended to bend and larger trees tended to lose mostly crown branches. Dominant and codominant trees had greater crown loss than trees in lower canopy positions. Ice damaged plots had fewer healthy trees in 1998 than when previously evaluated.

Hardwood species received the most damage. A variety of species were damaged, as reflected by data from the Vermont Hardwood Health Survey plots (Figure 2).

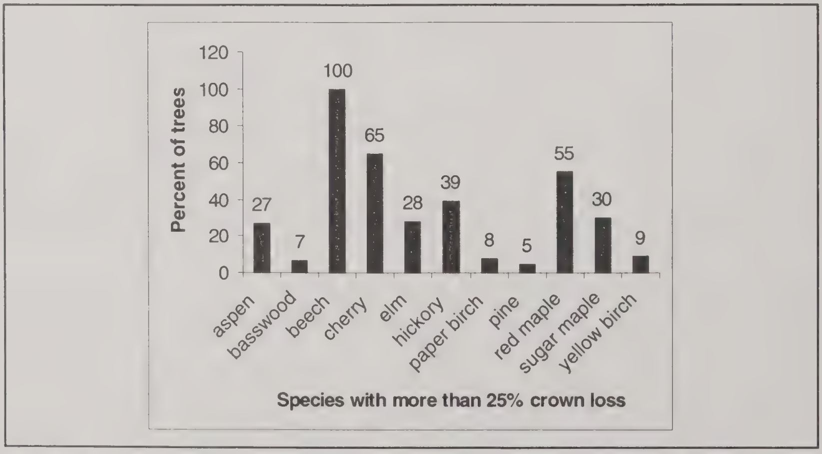

Figure 2. Upper canopy trees in ice-damaged Vermont Hardwood Health Survey plots that received significant crown loss, by species

Future Plans

Permanent plots will be revisited for crown ratings and other forest health measurements. Additional surveys will be conducted for sugarbushes and for urban and roadside trees. Damaged trees are being sawed and the lumber examined before and after kiln drying to identify hidden losses in value due to the stress of ice loadings. Special intensive monitoring plots in heavily damaged and nondamaged areas will be established to better evaluate vegetative changes. This will include crown and canopy photography to document changes over time. Plans are also being made to dissect sugar maple and white ash trees with ice wounds that occurred 10 or more years ago to look at extent of discoloration and decay associated with those wounds.

Evaluating trees with varying amounts of damage over time should provide better answers on survivability and recovery of different tree species and forest stands following a major ice storm. Thus, the next time a major event such as this occurs, there should be better information to provide to foresters, sugarmakers. and landowners seeking advice on how to best manage their damaged trees.

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Impacts of the January 1998 Adirondack Ice Storm on Wood and Fiber Supply

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Abstract

Published data on wood prices and first-person accounts of wood supply conditions are used to determine the impact of the January 1998 Adirondack ice storm on primary wood products manufacturing facilities from a wood and fiber supply perspective.

Introduction

On January 6–9, 1998, a major ice storm temporarily paralyzed a six-county area of upstate New York's Adirondack region. Power outages in some rural communities lasted as long as 2 weeks. Transportation systems came to a standstill, and schools were closed for days on end. In the region's forests, nearly 148,258 hectares (60,000 acres) of private land and 242,155 hectares (98,000 acres) of state land were damaged, with total losses nearing $16 million.[1]

For the people who worked in those privately owned forests harvesting timber for the region's forest products companies, the impacts were immediate. Harvesting operations were forced to shut down temporarily, because ice as thick as 7.6 centimeters (3 inches) coated the roads, making driving virtually impossible.

But what type of impact did this "storm of the century" have on wood and fiber supply for the region's primary manufacturing facilities, such as paper mills, sawmills, plywood fabricators, and other businesses that process roundwood into products? This paper examines that issue by addressing two key questions.

1. Did damage caused by the storm impact wood and fiber supply to the degree that primary manufacturing facilities were forced to shut down for lack of wood?
2. Did the number of trees damaged by the storm result in an over supply of wood on the market?

The senior author's firsthand experience as woodlands manager for Finch, Pruyn & Co., Inc., a Glens Falls, NY-based manufacturer of premium printing and writing papers, indicated that the answer to both questions was no.

On an annual basis, Finch, Pruyn converts more than 634,900 metric tons (700,000 tons) of wood into 217,680 metric tons (240,000 tons) of paper. More than 35 percent of the wood used at the company's mill is derived from the five New York counties most severely impacted by the storm—Jefferson, Franklin, Clinton, St. Lawrence, and Essex. But despite the fact that Finch, Pruyn's wood inventory was already lower than usual at the time of the storm, and even though wood deliveries to the mill were slowed for approximately 1 week following the storm, the mill was able to continue operating at full production.

To test our experience against that of other primary manufacturers, research was conducted via searches of storm-related Internet web sites, phone

[1]Data compiled by Empire State Forest Products Association, Albany, NY, February 10, 1998.

interviews with representatives of primary manufacturing facilities located in the storm's path, and reviews of stumpage, roundwood, and lumber prices in the months immediately following the storm.

Internet Research

Visits to web sites developed by New York State, Vermont, Maine, the Federal Emergency Management Administration, and many other organizations revealed tremendous differences in the attention given the storm, especially by each of the three states.

Maine's site offered a wealth of technical information and maps. Vermont's site listed a number of papers written about the storm. New York's site, on the other hand, offered very little information on the storm one year after the fact—although it was unclear as to whether the information had been removed or never existed.

Overall, the sites provided volumes of information on the human and urban impacts of the storm, as well as damage caused to the agricultural industry—most notably, the maple syrup industry and dairy farms. In some cases, this information was presented in minute detail: 351 maple sugarbushes impacted, 1,400 out of 1,800 dairy farms. Yet no references to an impact—positive, negative, or nonexistent—on wood and fiber supply could be found.

Survey of Primary Manufacturing Facilities

In the weeks following the storm, the Empire State Forest Products Association (ESFPA) conducted a survey to gauge the impact of the event on its members. A review of the results of this survey indicated that, in addition to the nearly $11 million in forest damage cited earlier, $2.5 million in infrastructure damages and lost production could be traced to the storm.[1] The majority of these production losses, however, resulted from physical damage to manufacturing plants due to flooding, not from lack of wood.

Follow-up phone calls were then made to the 7 ESFPA members located in the path of the storm and to 15 or so independent timber harvesters who traditionally work in that region. The questions posed to these industry representatives were as follows: Did you see an impact on wood supply, negative or positive, as a result of the January 1998 ice storm? And do you believe that an impact will be felt at some point in the future?

Not one mill reported having to shut down or reduce production due to lack of wood, and none of the harvesters reported that their work had been impacted more than during other types of prolonged poor weather.

Although some of the smaller mills and harvesting operations reported an over supply of wood in the immediate aftermath of the storm, it is likely that these were localized occurrences, as none of the state or regional data referenced confirmed such an impact.

Several of the smaller processing facilities located in the storm's path speculated that they may be hampered by a lack of available wood decades down the road, primarily because the small size of their business makes it economically infeasible for them to travel beyond their immediate procurement area. Given the difficulty this natural resource-based industry faces in anticipating changes even 5 years down the road, however, it is nearly impossible to plan ahead or adjust operations in anticipation of such events.

One sawmill operator also reported that the sugar maple being salvaged after the storm produced lumber that was not as bright as expected and did not attract as high a price. Overall, however, there was little evidence that wood supply was impacted by the storm.

Market Research

In a final attempt to disprove the theory that the January 1998 ice storm resulted in no significant impact to wood and fiber supply for New York's

primary forest products manufacturing facilities, we turned to published price reports for stumpage, delivered roundwood, and hardwood lumber for the months leading up to and following the storm.

For hardwood and softwood sawlog and pulp stumpage, we compared prices in the regions impacted by the ice storm to prices in the nonimpacted, western portion of the state and found no significant variations. Prices for northern hardwood lumber and pallet lumber remained relatively unchanged for the period.

In short, these reports indicated no pricing trends—positive or negative—that could be attributed solely or confidently to the storm. A representative sample of pricing charts is shown in Figures 1–8. The regional prices in Figures 1–6 are for the following counties:

Region B—Chemung, Genesee, Livingston, Monroe, Ontario, Orleans, Schuyler, Seneca, Steuben, Wayne, and Yates Counties
Region D—Jefferson and Lewis Counties
Region F—St. Lawrence County
Region L—Clinton, Essex, and Franklin Counties

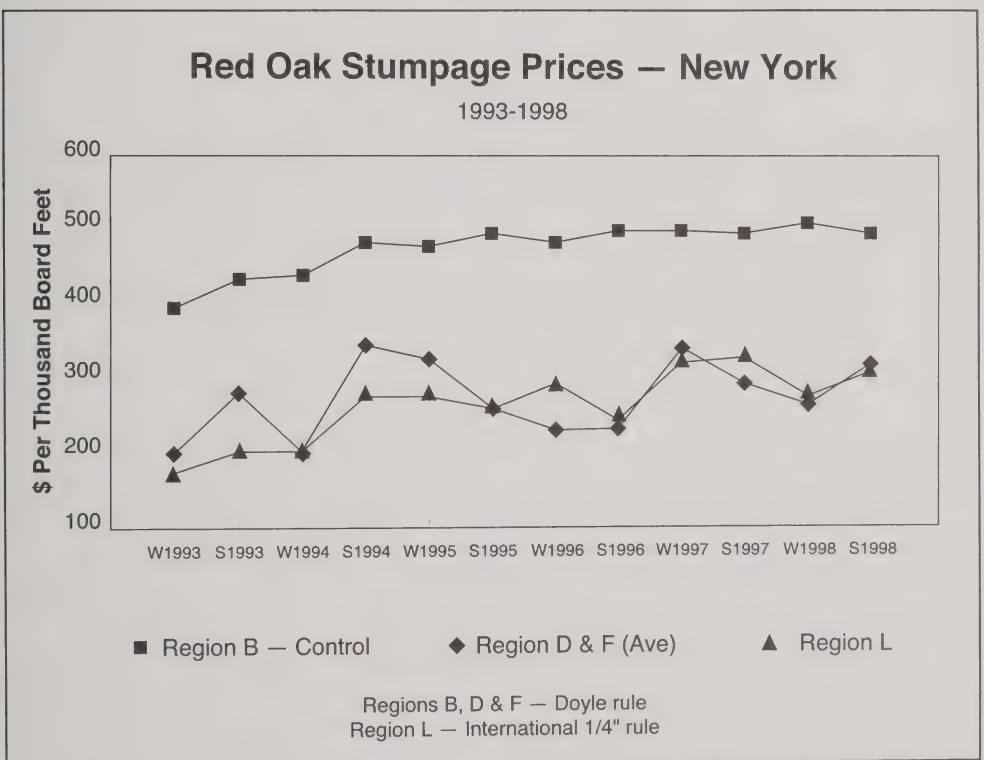

Figure 1. Red oak stumpage prices in New York State, 1993–98. Data compiled from New York State Department of Environmental Conservation, Division of Lands and Forests, Stumpage Price Reports.

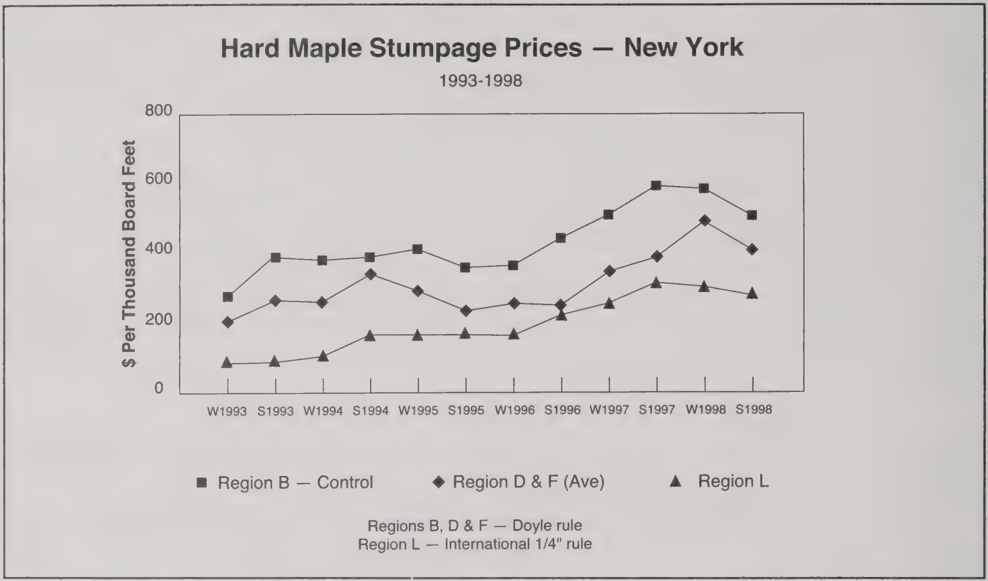

Figure 2. Hard maple stumpage prices in New York State, 1993–98. Data compiled from New York State Department of Environmental Conservation, Division of Lands and Forests, stumpage price reports.

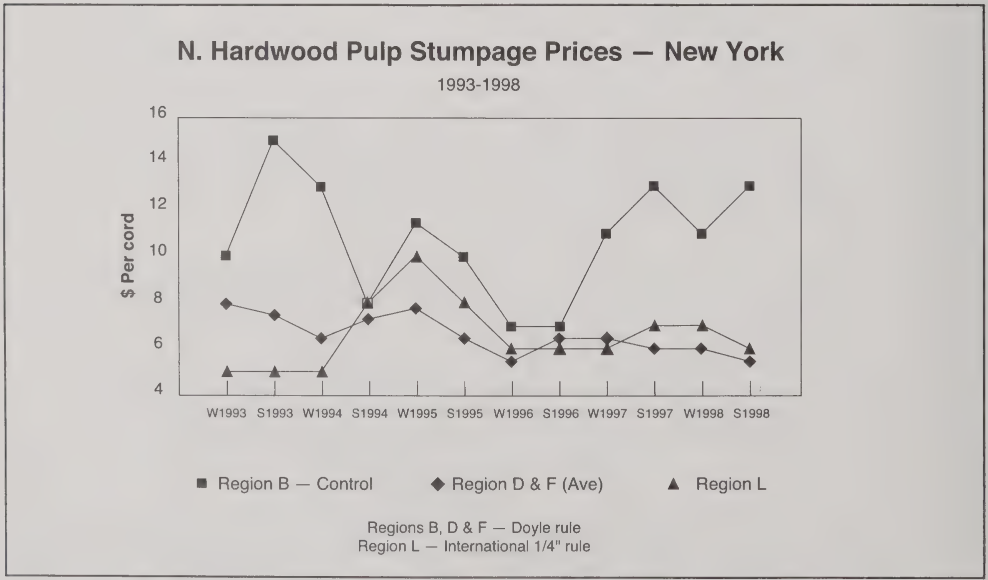

Figure 3. Northern hardwood pulp stumpage prices in New York State, 1993–98. Data compiled from New York State Department of Environmental Conservation, Division of Lands and Forests, stumpage price reports.

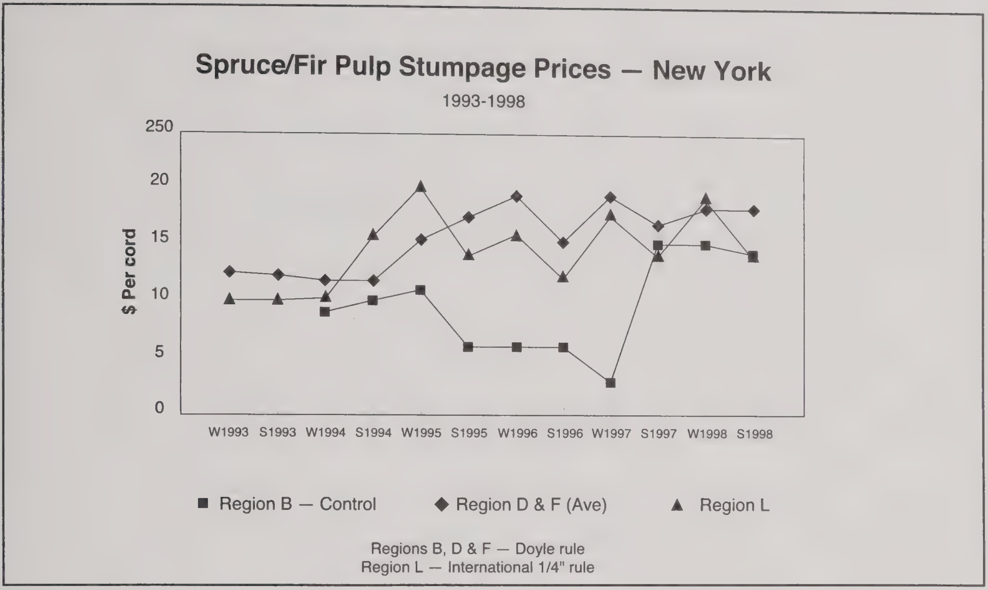

Figure 4. Spruce/fir pulp stumpage prices in New York State, 1993–98. Data compiled from New York State Department of Environmental Conservation, Division of Lands and Forests, stumpage price reports.

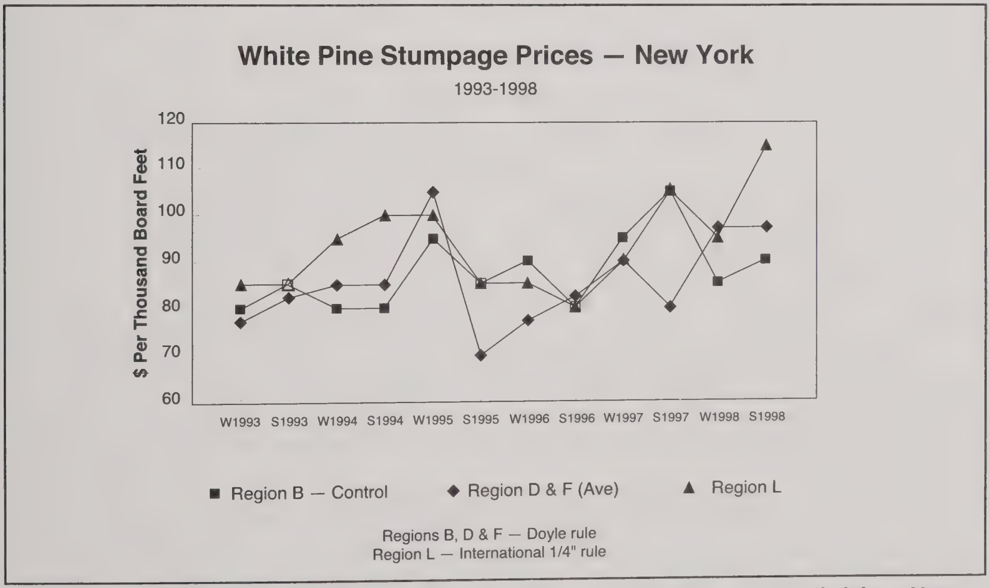

Figure 5. White pine stumpage prices in New York State, 1993–98. Data compiled from New York State Department of Environmental Conservation, Division of Lands and Forests, stumpage price reports.

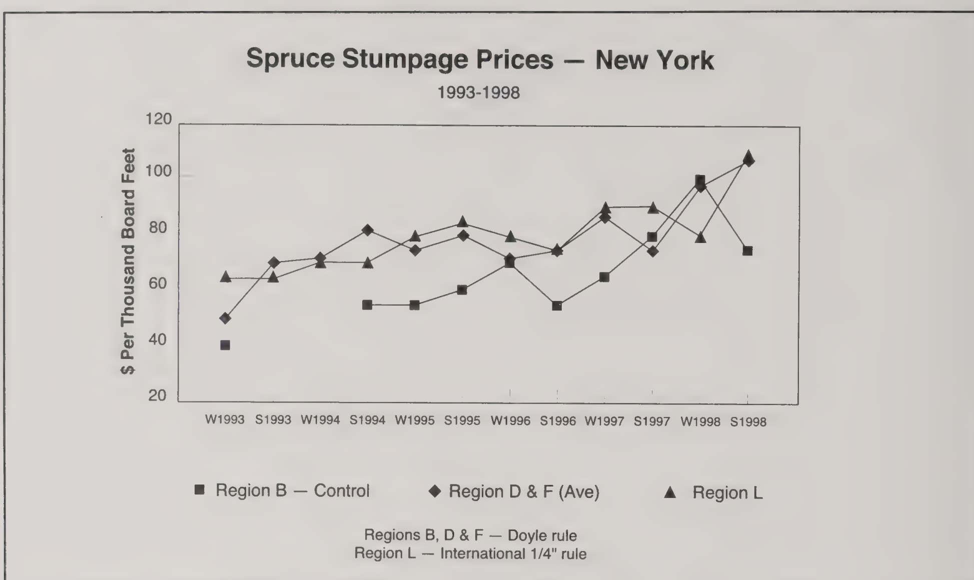

Figure 6. Spruce stumpage prices in New York State, 1993–98. Data compiled from New York State Department of Environmental Conservation, Division of Lands and Forests, stumpage price reports.

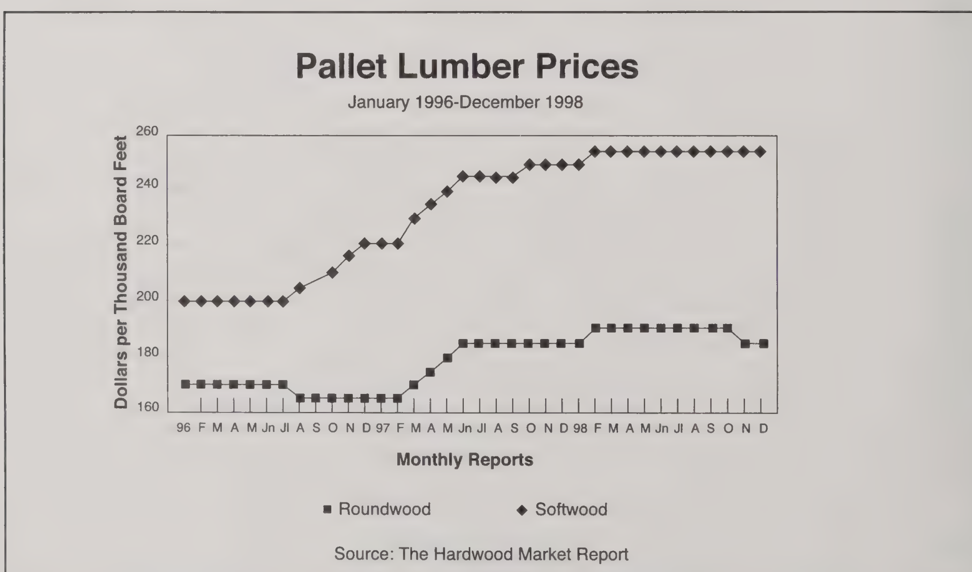

Figure 7. Pallet lumber prices in New York State, January 1996–December 1998. Data compiled from the Hardwood Market Report.

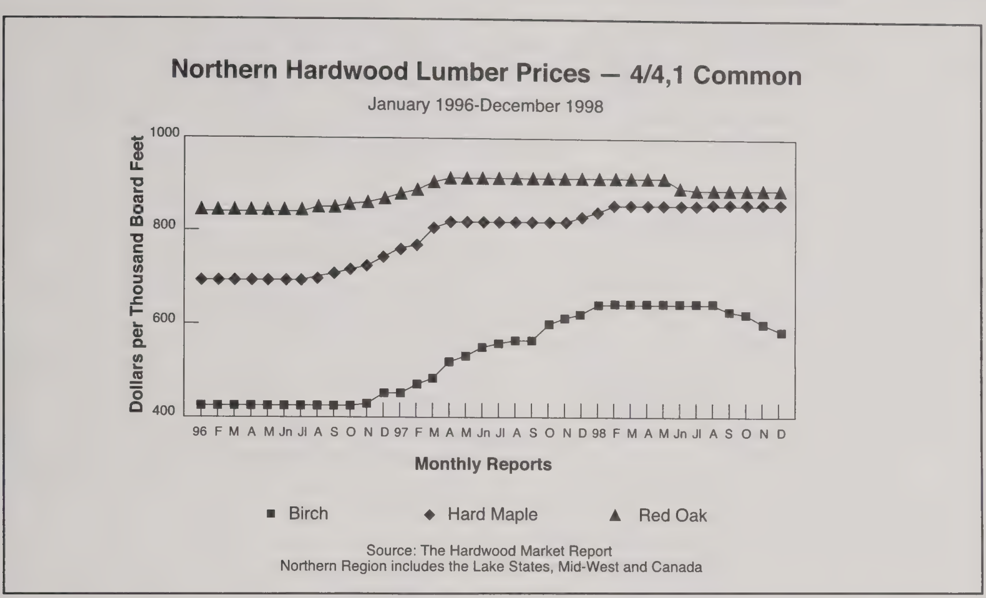

Figure 8. Northern hardwood prices in New York State, January 1996–December 1998. Data compiled from the Hardwood Market Report.

Analysis

At first glance, it may seem nearly impossible that an industry dependent on a consistent and plentiful supply of wood was not impacted by a major natural disaster over a wide expanse of forestland. The reasons behind this minimal impact are several, and quite straightforward, however.

First, there is no doubt that, while the storm was raging and in the days immediately following, there was a reduction in wood coming out of the five-county area impacted. Timber harvesters were simply unable to get into the woods to work and were often involved in urban cleanup and humanitarian activities.

But it is important to remember that events like the ice storm of January 1998 are not new. In fact, effects of natural disasters such as ice, wind, fire, insects, and disease are relatively consistent parts of the wood and fiber supply equation. Forest products companies plan for these unpredictable events by building up and maintaining high levels of wood inventory as insurance against possible short-term fluctuations in supply.

In addition, when it comes to wood supply, storms quickly reach a threshold beyond which their impact is inconsequential. For example, 3.5 millimeters (1/8 inch) of ice coating a road is dangerous enough to keep timber harvesters out of the woods. Should that coating grow to 7.6 centimeters (3 inches), the impact on the harvester remains the same.

For that reason, the severity of the January 1998 ice storm had no greater impact on harvesting operations from a wood and fiber supply perspective than the much less severe ice storms experienced in early 1999 or the disruption that occurs during a week of spring rains—with the obvious exception of the danger and difficulty of moving through the woods.

The vast number of damaged trees left in the storm's wake did not result in an over supply of wood on the market, either, as the capacity of loggers to harvest the wood and forest products companies to use it did not change.

New York's forest products companies did not add new production capacity because of the short-term availability, nor did timber harvesters purchase additional harvesting equipment. As one landowner reported, planned harvests of standing timber were simply postponed and operations were moved into a salvage mode. As a result, the same volume of wood was removed from the forest as would normally have occurred.

Also, helping to prevent an over supply of wood was the well-reasoned advice given to small nonindustrial landowners by forestry professionals in the wake of the storm: "don't panic." Trees damaged by ice can and will survive, as compared to trees felled by severe wind. There was no compelling need for landowners to rush into a salvage operation . . . and they did not.

Finally, the abundance of healthy, productive forests in New York State also helped to mitigate the impacts of the storm. New York's forests are growing three times as much wood on an annual basis than is harvested or lost to weather disasters, disease, or insects. In addition, many roundwood users purchase wood from a wide, multistate procurement region. Any temporary shortage of wood in one area can typically be set off by wood harvested elsewhere.

Conclusions

The ice storm of January 1998 brought with it considerable loss, both personal and financial, to landowners and others across New York's Adirondack region. From a silvicultural standpoint, forests were devastated and will take many years to fully recover. But when it comes to the issue of wood and fiber supply, our firsthand experience and considerable research shows that the ice storm was simply another bump in what is always a bumpy wood procurement road.

As noted forestry expert Lloyd Irland wrote of the ice storm in the September issue of the respected Journal of Forestry: "No hardwood pulpwood glut has yet emerged" (Irland 1998).

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Recommended Forest Management Responses to the January 1998 Ice Storm

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Abstract

Silvicultural recommendations that were offered shortly after the ice storm are still generally applicable. The message "Don't panic, be safe, and get professional advice" is important when managing ice damaged stands. At this early date, hardwoods show little sign of discoloration in the sawlog portion of the bole. Ash and black cherry resprouted vigorously in one growing season. It appears that for moderately damaged hardwoods, it may be advisable to wait another year or two before making management decisions. Although some managed stands were more heavily damaged than unmanaged stands, wide scale ice storms are not a frequent event so it is not necessary to thin a stand lighter than usual to lessen the chance of ice damage.

Introduction

Shortly after the January 1998 ice storm, Bill Leak and I offered seven silvicultural considerations for managing ice damaged stands (Lamson and Leak 1998). We emphasized how important it is to evaluate the damage, maintain stocking at the B-line, guard against epicormic branches, consider group selection, concentrate on sawtimber and large poletimber stands, consider wildlife trees, and avoid residual stand damage. In this paper, I will discuss these considerations in light of what we have learned over the last year.

The message "Don't panic, be safe, and get professional advice" was widely publicized shortly after the ice storm. This is still good advice for people working in ice damaged stands.

- Don't panic—There is time to consider alternatives and make decisions. Most severely damaged softwoods have already been attacked by insects, which has lead to blue stain. There is little chance of salvaging high quality logs from these trees. As was predicted, discoloration in hardwoods has not substantially reduced log value. It will likely be several years before discoloration and stain from wounds in the tree crowns will reach the lower portions of the boles.
- Be safe—There are still many broken limbs and treetops precariously hanging in the trees. Many loggers are using mechanized harvesting to reduce the risk while working in ice damaged stands.
- Get professional advice—Both public and private foresters have learned a lot about handling ice damaged stands in the last year and are a ready source of information.

Silvicultural Recommendations

Evaluate the Damage

It is important that forest landowners accurately estimate the damage to their stands. A professional forester can best do this. It is usually necessary to take some sort of inventory to estimate the severity of damage. Generally, three classes of ice damage are recognized for standing trees: less than 50 percent crown loss, 50–75 percent crown loss, and over 75 percent crown loss. Trees with less than 50

percent crown loss have a good chance of fully recovering. Trees with 50–75 percent crown loss can be retained, but may develop stain and decay, and because of this should be reevaluated in 3 to 5 years. White ash and black cherry resprouted vigorously last summer and appear to have the best chance of fully recovering. Trees with over 75 percent crown loss are at risk of dying or of heavy infestation by insects and diseases and should be considered for harvest.

Conifers, if stressed enough by crown loss, were attacked by bark beetles and wood borers last summer, especially trees that were not vigorous. Along with these insects came blue stain, which may degrade the value of lumber sawed from infested trees. Severely damaged, low vigor conifers and downed conifers should be salvaged as soon as possible. There is no immediate need to harvest standing, living hardwoods. The spread of discoloration and decay in hardwoods is much slower than it is in conifers. Downed hardwoods will be degraded within one or two growing seasons.

Maintain Stocking

To minimize development and persistence of epicormic branches on hardwoods and to maintain optimum volume growth per acre, stocking should remain at or slightly above the B-line (optimal stocking—about 15 meters^2/hectare [65 feet^2/acre] for hardwoods and 23 meters^2/hectare [100 feet^2/acre] for conifers). B-level stocking can be visualized as removing about every third tree from a fully stocked stand. If removing all the ice damaged trees would reduce the stocking below the B-line, then it might be appropriate to leave some of the less severely damaged trees. A new stocking guide for managed white pine stands has been published which shows the B-line at about 23 meters^2 (100 feet^2). (Leak and Lamson 1999).

Should thinnings be lighter than is generally recommended to make stands more resistant to future ice storms? It appears that some managed stands were more severely damaged than unmanaged stands, except where there was heavy ice damage. However, because wide scale ice storms are not frequent events, it is not necessary to thin lighter to lessen the chance of ice damage. Many foresters are aware of relatively small areas that have a history of fairly frequent ice storms. In these areas, it may be advisable to thin lightly or not all to reduce the risk of damage.

Guard Against Epicormic Branches

Exposure to light can lead to epicormic branching on hardwood species. If the stocking is below 18 meters^2/hectare (80 feet^2/acre) in northern hardwood stands, these newly formed epicormic branches may persist and lead to lower timber quality. Epicormic sprouting is of less concern (i.e., less sprouting occurs and it is higher on the bole) in dominant trees with full crowns compared to understory trees and trees with lower levels of damage. It may be advisable to retain some damaged trees to reduce epicormic sprouting on the highest value trees.

Consider Group Selection

The ice damage seemed to be very patchy in the Green and White Mountains. For example, 0.1 hectare (1/4 acre) of heavy damage may be adjacent to lightly damaged areas. Patches of heavily damaged trees are logical places for groups. Groups less than 0.1 hectare (1/4 acre) will have a high proportion of shade tolerant species, like beech and sugar maple. Groups over 0.3 hectare (2/3 acre) will have a higher amount of shade intolerant regeneration like fire cherry, aspen, and paper birch. Groups between 0.1 and 0.3 hectare (1/4–2/3 acre) will have a mixture of tolerant and intolerant species, as well as trees of intermediate tolerance like white ash, yellow birch, and red oak. Generally, group selection harvesting guidelines call for putting 10–15 percent of the stand area into groups at each stand entry. The entire stand would be cut over in 7 to 10 entries, or approximately 150 years, if a 15-year entry cycle is used. Improvement cutting is applied between the groups to reduce the basal area to about 16 meters^2/ hectare (70 feet^2/ acre). Trees harvested are those that would significantly decrease

in value and/or would release residual crop trees. It may be advisable to leave some dominant, fully crowned trees with little damage or defect within some larger groups.

Concentrate on Sawtimber/Large Poletimber Stands

Although sapling and regeneration stands may have a lot of bent over trees, some of these stems will recover from ice damage. If bent trees did not recover immediately after the ice melted, they probably will not. It would be advisable to reevaluate damaged sapling stands in 3 to 5 years. If patches have not fully recovered then perhaps consider group selection. For sawtimber and poletimber stands, usually 32–44 meters^2/hectare (5–7 cords/acre) or 28 meters^2/hectare (2,000 board feet/acre) are needed for a commercial harvest.

Consider Wildlife Trees

Not all damaged trees need to be removed. In particular, trees over 46 centimeters (18 inches) d.b.h. with broken tops or large broken limbs have a good chance of developing into valuable cavity trees for wildlife. This is true for both hardwoods and softwoods. It is a good idea to retain some of these damaged trees.

Avoid Residual Stand Damage

Damage to residual trees during salvage operations should be avoided. A wound on the butt log is far more serious in terms of economic value loss than a wound from a broken limb in the crown. It makes little sense to harvest storm damaged trees if the residual trees are damaged in the process. Some things to consider are as follows:

- Mark trees to be removed on both sides of the stem and near groundline. This allows the harvester to see cut and residual trees from all angles, which helps to reduce residual stand damage.
- Do not harvest during the spring when soft ground will cause excessive root injury. If possible, do not harvest during the growing season (May-July) when the bark is "slipping." residual trees are much more susceptible to wounds caused by felling and skidding during the growing season.

Conclusions

Every stand is different and each landowner has unique goals for his or her property. These general guidelines can help landowners and professional natural resource managers make decisions about managing ice damaged stands, but they must be tempered with knowledge of local ecology and economic conditions.

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Summary of Research Projects That Address Damage Caused by the Ice Storm of 1998

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Introduction

As a result of the ice storm, questions were raised as to the long-term impact on trees, forest stands, and wildlife, as well the effects on forest resources and landowners. The Federal Emergency Appropriation for the recovery included funds for studying long-term effects. The following list describes the various projects that have been initiated or proposed in each of the affected states and the project contact.

Maine

Tree Damage—Investigating long-term damage from ice storm injury, related to stocking and stand condition, and post-storm harvest impacts. Looking at various stand conditions: precondition (undamaged stands), damaged stands, and post harvest stands. Planning training sessions to share management recommendations based on research. *(Bill Ostrofsky, University of Maine, Orono, ME)*

Secondary Insect Impacts—Conducting general surveys for various insect pests such as callous borers, sugar maple borers, bronze birch borer, and ambrosia beetles. Planning to compare previous years' insect populations with future population development. Have already observed significant increases in beetle populations in affected red pine plantations. Will also be looking at potential build up of larch beetle populations. *(Dick Dearborn, Maine Forest Service, Entomology Lab, Augusta, ME)*

Aerial Photography—Planning to compare current true color (1:9,000 scale) photography to aerial photos obtained 5 and 10 years after the storm to determine change in stand condition. The information on the photos will be augmented by information from permanent plots within the photographed area, including Forest Health Monitoring plots, Forest Inventory and Analysis plots, Beech Survey plots, and Birch Survey plots. *(Dave Struble, State Entomologist, Maine Forest Service, Augusta, ME)*

New Hampshire

Land Cover Type Mapping—Developing digital mapped data layer to support identification and assessment of areas damaged during the ice storm. Cooperative effort will rely on remotely sensed data (Landsat Thematic Mapper imagery) and imaging radar data (Radarsat, ERS-1, ERS-2) to characterize landscape "patches." The project will incorporate a pre-event vegetation type map of susceptible areas above a specific elevation and post-event imagery to provide data on specific locations of damage. The overlay will provide an assessment of damage areas by location and vegetation type, and provide baseline information to managers to assist in monitoring long-term impacts. *(Barry Rock, Complex Systems Research Center, University of New Hampshire, Durham, NH)*

Natural Heritage Assessment and Management—Assessing the condition of rare plant populations and natural communities

influenced by the ice storm. Planning to identify appropriate management actions to ensure their survival. Currently, there are 281 occurrences on non-Federal lands in New Hampshire. Planning reconnaissance on the ground in storm damaged areas to assess condition, habitat, and management options. Will coordinate with the White Mountain National Forest working on USDA Forest Service lands. *(New Hampshire Division of Forests and Lands, Concord, NH)*

Wildlife Habitat—Working within ice storm damaged areas to develop long-term plans for ice damage recovery, forest stewardship, and wildlife habitat conservation. Collaborating with New Hampshire Fish and Game Department, Regional Planning Commissions, and Conservation Commissions. *(Extension Wildlife Specialist, Cooperative Extension, University of New Hampshire, Durham, NH)*

Amphibian Populations—Researching amphibian responses to changes in forest structure associated with ice storm damage. Studying changes in amphibian populations, which can potentially have a significant impact on the forest food web. Provides a model for examining the effects of natural disaster events. *(Kimberly Babbitt, University of New Hampshire, Durham, NH)*

New York

Cornell University

Evaluation of SIP as a Tool in Technical Assistance for Landowners with Ice Storm Damage—This project will evaluate the delivery of technical assistance to ice storm victims in hopes of improving the program. The initial awareness and perceptions of the Stewardship Incentive Program (SIP) by landowners will be evaluated. The understanding of landowners, DEC agency staff, and consulting foresters regarding how to apply for SIP funds will be assessed. The ease of the application process and the communication between the various agencies and landowners will be evaluated. Surveys will be sent out in 1999 to landowners, consulting foresters, DEC staff, and Farm Service Agency staff. Results should be available by late 1999. *(Principal Investigator: Tommy L. Brown)*

Assessment of Educational Efforts and Needs of Private Woodland Owners, Maple Producers, and Tree Care Professionals—This project will characterize the degree to which educational materials and programs have assisted landowners and if any additional educational assistance is needed. The characteristics of private woodland properties will be assessed using a separate stratum for maple producers. The characteristics of tree care professionals and situations that they most frequently were asked to assist with after the storm will be evaluated. The extent to which these three client groups were able to find and make use of the educational resources that would assist them in recovering from the ice damage will be determined. Lastly, the future education needs of each group and the most effective way to reach each group will be ascertained. Surveys will be sent out in 1999 to woodland owners, maple producers, and tree care professionals. Results should be available by late 1999. *(Principal Investigator: Tommy L. Brown)*

Ice Storm Impacts on Streamsides and Aquatic Habitats of the North Country—This project will focus on understanding the immediate and long-term impacts of the ice storm on streamsides in the North Country. The first component of the research will investigate the immediate impacts of the storm on riparian zone trees and assess the resulting effects on the fish and invertebrate communities and on physical processes in associated streams. The second component will consist of a long-term monitoring program of the recovery of the streamside and stream habitats. Data collection will be completed in the summer of 2000. *(Principal Investigators: Rebecca Schneider and Cliff Kraft)*

Ice Storm Recovery for Sugarbushes in Northern New York—This project will investigate the effects of the ice storm on sugarbushes by examining growth rates, stocking levels, tree vigor, and quality over time (resulting from stem wounding and incidence of decay), changes in successional patterns and invasion of species, rate of

compartmentalization of taphole wounds, and increased susceptibility to additional stresses such as insects and disease. To meet these goals, permanent plots will be set up in the impacted areas that were active in sap production prior to the storm, and these plots will be remeasured over a 20-year period. *(Principal Investigators: Lewis Staats, Marianne Krasny, and Peter Smallidge)*

Urban Canopy Monitoring—The first component of this study is a retrospective look at the trees damaged in the Rochester (Monroe County) 1991 ice storm. The conclusions from the Rochester data will supply hypotheses for a sound urban canopy monitoring project in the North Country. The second component of this study is a parallel study of the rural North Country forest recovery that has already been initiated. Specific goals are to determine the long-term results of urban storm damage, evaluate the consequences of leaving trees with 50–70 percent crown damage, provide better guidelines for tree managers, and supply North Country personnel with assessment training for future disasters. Data collection will be complete by the summer of 2000, and funds will be sought for a remeasurement in 2002. *(Principal Investigator: Jerry Bond)*

SUNY-College of Environmental Science and Forestry

Forest Plant Communities—The objectives of this study are to quantify the effects of the 1998 ice storm on the forest plant community and to determine what silvicultural strategies might be recommended following future similar weather events. Specifically, the project will focus on relating post-damage condition and future tree growth to the pre-storm canopy position, species, and size. The structural changes in the forest plant community will be described in relation to the effects on plant and animal habitat. *(Principal Investigator: Don Leopold)*

Forest Health—This study will focus on the effects of the ice storm on forest health. The relative amounts of individual tree species and forest types in the region will be determined, and the relative amount of damage in each will be assessed. The effects of forest management on the impacts of and recovery from the ice storm will be investigated. Additionally, this study will examine the relationship between previous disease induced defects and damage from the ice storm. *(Principal Investigator: Paul Manion)*

Wildlife Communities—This project focuses on two aspects of faunal communities in stands affected by the ice storm: (1) faunal diversity response to disturbance and potential forest management alternatives, and (2) the interaction of deer and regenerating plant communities. Species abundance, richness, and diversity of breeding birds, amphibians, land snails, ground beetles, and burying beetles at broad and local scales will be investigated. How forest floor complexity affects amphibian invertebrate communities and how tree species composition and management practices affect songbird and beetle communities will also be examined. The project will investigate the effects of deer browsing on overall stand composition and relative abundance of high value (e.g., sugar maple) and low value (e.g., beech) tree species, if deer affect regeneration differently in highly disturbed areas compared to relatively undisturbed areas, and if deer browsing intensity can be predicted by local and landscape scale characteristics (e.g., scale of disturbance, distance to agricultural areas). *(Principal Investigator: James Gibbs)*

Forest Insects—Evaluating the economic impacts of various bark beetles and woodborers on commercially valuable northern hardwood and white pine in stands heavily damaged by the ice storm of January 1998. Increased damage by sugar maple borer, peach bark beetle, and several species of ambrosia beetles are anticipated in high value northern hardwoods. It is expected white pine will be subjected to degrading activities of ambrosia beetles, red turpentine beetles, and sawyer beetles. The impact of these secondary insects on potential sawtimber quality wood will be assessed 2 to 4 years post storm damage. Additionally, secondary insect diversity, relative abundance, and temporal patterns in damaged and undamaged stands will be investigated. *(Principal Investigators: Douglas Allen and Stephen Teale)*

Economic Impact Analysis—The financial impacts of the ice storm on forest resources will be studied with an emphasis on short- and long-term impacts on timber and forest related recreation. This project will be carried out during Phase II only and will use much of the biological data gathered by other teams. *(Principal Investigator: John Wagner)*

Social and Policy Issues—This project will investigate public policy questions associated with disturbance events such as the 1998 ice storm. The questions to be addressed are as follows: (1) What threat, if any, do increased fuel loads present to local landowners? (2) What are the regulatory problems affecting sanitation and salvage in the area? (3) What, if any, public assistance should be available to private forest owners to assess and monitor forest health? (4) What public-private partnerships can be pursued to sustain better management of forest health in the Northern Forest? and (5) How have communities and local governments responded to the loss of street trees? To address these questions, a literature review of forest health policy in response to disturbance events will be performed, municipal ordinances will be gathered from county law libraries, and the methods used by other states in formulating and implementing policy on forest health will be assessed. *(Principal Investigator: Don Floyd)*

NY Department of Environmental Conservation and St. Lawrence University

Remote Sensing—This project involves the utilization of satellite imagery to precisely locate and describe the degree of forest cover damage resulting from the January 1998 ice storm. Current forest damage data were collected via aerial sketchmapping with additional processing. This information is of a small scale and tends to generalize damage intensity, as it ignores small intensely impacted or well protected components of forest stands. It is hypothesized that greater detail of damage intensity and smaller, more specific locations of isolated forest cover impact may be determined through use of modern satellite technology. *(Kurt Swartz, DEC and William T. Elberty, St. Lawrence University)*

Vermont

Impact on Butternut—Evaluating butternut trees in the Champlain Basin of northwestern Vermont to determine the overall extent and impact of ice damage. Evaluating the extent and impact of ice damage on other tree species growing in association with butternut. *(Dale R. Bergdahl, Department of Forestry, University of Vermont, Burlington, VT)*

Bird Populations—Assessing changes in breeding bird populations in ice damaged forests. Investigating the effect of the ice storms on the relative abundance, diversity, and composition of forest breeding bird populations in Vermont. *(Steve Faccio, Staff Biologist, Vermont Institute of Natural Science, Woodstock, VT)*

Growth and Survival of Sugar Maple—Examining the relationships among crown damage, root and stem carbohydrate storage, and subsequent growth and survival in sugar maple trees in stands in Vermont. *(Timothy Perkins, Proctor Maple Research Center, University of Vermont, Burlington, VT, and Betty Wong, USDA Forest Service, Northeastern Research Station, Burlington, VT)*

Crown Canopy Changes—Following the recovery or decline of tree crowns in ice damaged stands compared to nearby nondamaged stands using image analysis as a means to monitor changes over time in canopy cover, leaf area, and standard crown health ratings. *(Ronald Kelley, Vermont Department of Forests, Parks and Recreation, Stowe, VT)*

Remote Sensing—Assessing ice-affected foliage using remotely sensed infrared imagery to detect ongoing stressed vegetation. Attempting to provide additional information on the location and extent of forest damage based on visible imagery analysis. *(Lesley-Ann Dupigny-Giroux, University of Vermont, Geography Department, Burlington, VT)*

Changes in Forest Stands—Monitoring changes in growth, composition, and health throughout the forest vegetation structure in a severely damaged ice stand and comparable undamaged site on state-owned land in Vermont. *(Jay Lackey, Vermont Department of Forests, Parks and Recreation, Barre, VT, and Florence Peterson, USDA Forest Service, Forest Health Protection, Durham, NH)*

Ecological Effects—Monitoring long-term ecological effects on vegetation using monitoring plots at Shaw Mountain Preserve. *(Ana Ruesink, Vermont Nature Conservancy, Montpelier, VT)*

USDA Forest Service

Response of Forests—Monitoring the response of the entire plant community, including herbaceous and understory woody species dynamics, to openings created by the ice storm. Assessing the fate of injured trees. Using detailed, permanent vegetation study sites to be located throughout Vermont, New Hampshire, and Maine. *(Christopher Eagar, USDA Forest Service, Northeastern Research Station, Durham, NH)*

Tree Damage—Examining the damage caused by ice storm injury to northern hardwoods. Determining the effect of crown loss due to ice injury on stemwood formation 5 years after injury and the effect of wood exposure on wood quality. Assessing the types of wood stains and rots that develop after injury. Creating a library of digital images to produce photo guides and educational materials. Study trees located in Maine, New Hampshire, and Vermont. *(Walter Shortle and Kevin Smith, USDA Forest Service, Northeastern Research Station, Durham, NH)*

Stress Detection—Assessing short- and long-term ice damage through detection of stress in foliage using biochemical markers. Selecting trees in various damage categories to collect samples of visually healthy leaves and establish the relationship between the stress marker, putrescine, and tree recovery. *(Rakesh Minocha, USDA Forest Service, Northeastern Research Station, Durham, NH)*

Monitoring Tree Health in Ontario After the Ice Storm

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Introduction

Ice storms are a common occurrence in the forests of eastern North America; Van Dyke (1999) reviewed the chronology of ice storms for this region. Some workers have noted the role of this disturbance in forest succession (De Steven and others 1991, Lemon 1961) and others have implicated the role of ice damage in initiating forest declines (Nicholas and Zedaker 1989). Damage to trees after an ice storm depends on a number of variables including ice thickness, elevation, slope exposure, wind velocity, crown form, and stand density (Seischab and others 1993, Sissini and others 1995). Susceptibility to breakage after an ice storm also differs with tree species. The relative susceptibility of tree species found through eastern Canada can be approximated from earlier works (Croxton 1939, Downs 1938, Hauer and others 1993, Lemon 1961, Rebertus and others 1997, Seischab and others 1993); a comprehensive review of tree susceptibility literature is provided by Van Dyke (1999). Generally, though, conifers are less susceptible to ice damage than hardwoods as they have smaller upper crowns and branching habits better suited for supporting weight (Carvell and others 1957).

In January 1998, a major ice storm affected northeastern North America. In Canada, damage occurred from eastern Ontario through to western New Brunswick. The most significant damage was reported in western Quebec and eastern Ontario. In Ontario, a total of 603,000 hectares were mapped as damaged to varying degrees. After the storm a joint Federal-provincial program was established to assess damage and to monitor the recovery of eastern Ontario forests. The program comprises a long-term research effort, as previously described by Lautenschlager and Nielsen (1999), and a forest health monitoring program. The following describes the latter program.

Materials and Methods

Following the storm the Canadian Forest Service (CFS) and the Ontario Ministry of Natural Resources (OMNR) conducted surveillance to determine the extent of the forest affected in eastern Ontario. Initially, forest health technicians from the CFS conducted an aerial mapping program. Visual sketchmapping was accomplished using a helicopter flown at about 60–100 meters above the forest canopy, with flight lines 5 kilometers apart. Eleven different categories were developed to describe damage to hardwood stands in this survey. These 11 categories were consolidated into 6 broader categories on the maps. Maps with areas of similar damage level were produced at a scale of 1:250,000 on National Topographic Series (NTS) sheets. These points were recorded on separate 1:250,000 NTS sheets. A geospatial database was then created from these paper maps. Areas of similar damage were digitized and each polygon was assigned a code to represent the level of damage within it. This produced a map showing broad areas of damage (Figure 1). Conifer damage was recorded as points of severe damage rather than areas of damage (Figure 2). In order to better estimate the area of forest affected, a satellite image with a resolution of 25 meters was obtained from the OMNR for the region of Ontario within Universal Trans Mercator Zone 18. The image contained 45 separate themes that were aggregated into 6 themes (water,

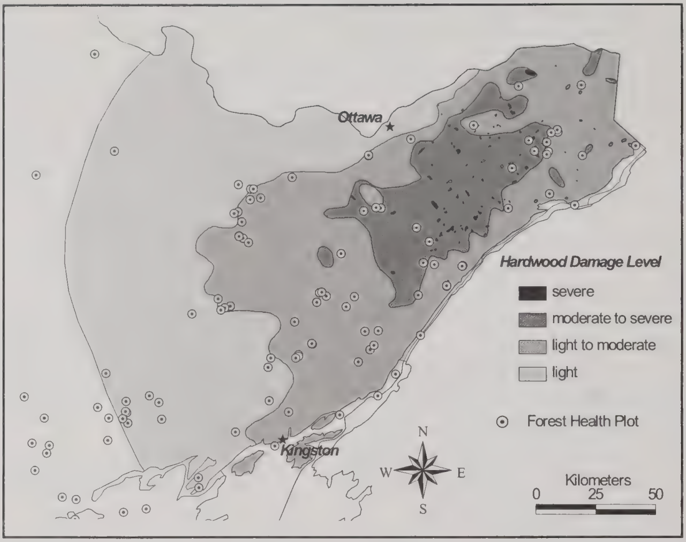

Figure 1. Map of eastern Ontario showing area within which ice storm damage to hardwood forest stands was observed during aerial mapping in January 1998. Locations of permanent plots used to assess damage and monitor recovery are also shown.

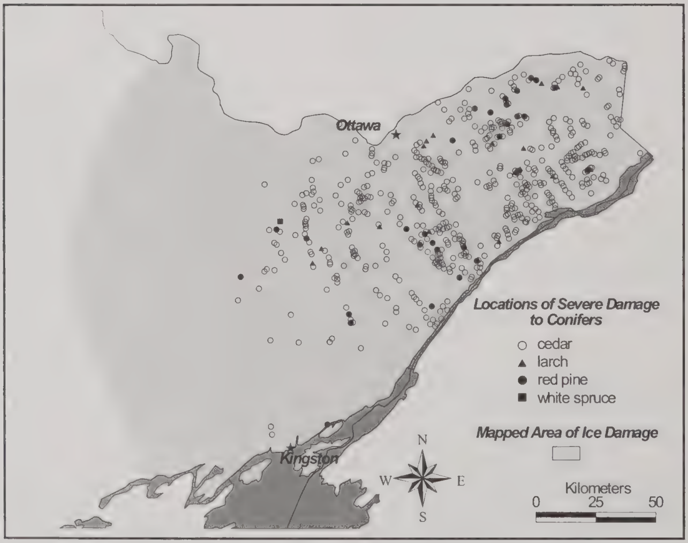

Figure 2. Map of eastern Ontario showing locations where damage to coniferous forest was observed during aerial mapping in January 1998

deciduous forest, mixed forest, coniferous forest, sparse forest, and other) for our purposes. This image provided land cover information necessary for the geospatial database to estimate the area of hardwood forested land affected by the ice storm (Table 1). Conifer ice damage estimates were calculated using a much simpler technique. The mean area of all pockets of damage for each conifer species was estimated. This area was multiplied by the number of observed pockets of damage to arrive at a total for each species.

Monitoring was also conducted on the ground to assess damage and long-term recovery for tree species. Preexisting plot locations were utilized as these provided information on stand conditions prior to the storm. In total, 26 plots from the CFS forest health monitoring system (Hopkin and Howse 1996) and 48 plots from the OMNR growth and yield program (Hayden and others 1995) were utilized for initial assessments of damage (Figure 1). Each stand was assessed prior to leaf out for crown damage and

Table 1. Area of forest effected by ice damage (in hectares)

Forest type[1]	Severe[2]	Moderate to severe[3]	Moderate[4]	Light to moderate[5]	Total
Deciduous forest	3,160	78,774	189,521	93,920	365,375
Mixed forest	838	25,363	80,344	81,269	187,814
Sparse forest	131	9,880	21,282	19,172	50,465
Total	4,129	114,017	291,147	194,361	603,654

[1]Deciduous forest: Hardwood forest or thicket swamp
Mixed forest: A combination of hardwood and conifer cover in the same stand; only hardwood component affected
Sparse forest: A combination of deciduous or coniferous cover in an open and scattered condition such as would occur on a rock outcrop; only hardwood component affected

[2]Severe: 50–100% of the trees within this area have greater than 75% branch loss, or downed or snapped off trees

[3]Moderate to severe: Greater than 75% of trees have 25–75% branch loss with the remainder of the trees severely damaged

[4]Moderate: Approximately 100% of trees have 25–75% branch loss; very few light or severely damaged trees observed

[5]Light to moderate: 25–75% of trees are moderately damaged and the remainder of the trees have less than 25% branch loss

whole tree mortality. Variables included the following:

1. Percentage of crown damage—a visual estimate was made of the percentage of the crown that was damaged (including an estimate of the portion of the crown broken out)
2. Number of primary and secondary branches broken within the crown
3. Estimate of existing crown with fine branching
4. Broken tops (conifers)
5. Stem damage—height and width of damage.

Plots were also assessed using North American Maple Project methodology (Millers and others 1991) during the 1998 growing season to asseso assess crown condition and tree mortality.

Results

Aerial mapping showed that approximately 365,000 hectares of deciduous forest sustained ice damage; a significant proportion of this area received moderate-to-severe levels of damage (Table 1). Damage to conifers was less continuous than hardwoods and appeared as "pockets" of damage within a stand. A total of 552 pockets of severe damage to conifers were observed, which amounted to a total estimated area of only 1,130 hectares (Table 2). The most common conifer species in eastern Ontario are red and eastern white pine, white spruce, eastern white cedar, balsam fir, and tamarack. Observations made during the survey suggested that white cedar was the most severely affected conifer, with a significant number of trees broken or bent. Other species showed more limited amounts of damage, mostly in the form of broken tops or leaders. Species such as red pine generally received little damage, although isolated pockets in older red pine plantations were severely damaged with broken stems. Many of the permanent plots within eastern Ontario contain a conifer component; however, only a limited number of plots contain large numbers of conifers. Accordingly, plot-based data on conifer condition are not reported here.

Hardwood species showed significantly more damage, although the levels were extremely variable between and within stands. On-the-ground measurements indicated 20 to 70 percent of overstory trees measured showed moderate to severe levels of crown damage depending on the species. Species with the greatest damage were basswood, beech, soft maple, and white birch; those showing the least damage were hard (sugar) maple, oak, ash, and hickory (Table 3). This generally agrees with previous findings (see Van Dyke 1999), although a concurrent study at Carleton University in Ottawa also found sugar maple to be highly susceptible (Fahrig 1999). Observations made by CFS personnel during the aerial survey suggested that poplar was the most severely affected by the storm; however, poplar was not well represented on the permanent plots.

The use of preexisting permanent plots has a number of disadvantages. The plots, which were set up to monitor forest health or for growth and yield studies, do not necessarily reflect the heterogeneity of eastern Ontario forests because species on the plots reflect the direction of previous studies. The plots contain a disproportionate amount of maple, and, as already mentioned, conifers are not well represented. The plots are not randomly distributed throughout the range of ice damage, although their preexistence does preclude bias in terms of their location with reference to damage. In spite of the disadvantages, this method was chosen, as it was important to have a record of tree condition prior to the ice storm in order to determine the effect of the storm. Information was available on species, status (dead/alive), tree height, d.b.h., and stem defects (conks, frost cracks, etc.), for all plot locations. In the case of forest health plots, additional information on insect and disease problems, and crown dieback and crown transparency also was available. These data will help to determine the direct effect the ice storm had on tree mortality and what role, if any, the health of the stand prior to ice damage may have on the recovery or further decline of stands in subsequent years.

The forest monitoring portion of the ice storm recovery program intends to monitor the health of affected tree species through visual assessments on

Table 2. Area of coniferous forest showing severe damage

Species	Number of locations	Average size of damage areas (ha)	Estimated total area damaged (ha)
Cedar	502	2	1,004
Red pine	29	1	29
Tamarack	19	5	95
White spruce	2	1	2
Total of all conifers	552	----	1,130

Table 3. Summary of ice storm damage to the crowns of dominant and codominant hardwood trees recorded on plots in the eastern portion of southern Ontario in 1998

Tree type	Total number of trees	Crown damage level[1] Trace	Light	Moderate	Severe
All hardwoods	1,926	37.5	36.3	19.9	6.3
Hard maple	1,081	37.8	42.5	16.8	2.8
Soft maple	110	41.8	16.4	28.2	13.6
Oak	275	31.3	47.6	17.8	3.3
Ash	152	59.2	17.1	19.1	4.6
Hickory	60	41.7	31.7	16.7	10.0
Basswood	125	11.2	17.6	36.8	34.4
Beech	27	18.5	18.5	55.6	7.4
White birch	26	30.8	19.2	30.8	19.2

[1]Trace = 0–5%, light = 6–24%, moderate = 26–75%, severe = 76–100%

permanent plots. Assessments using North American Maple Project methodology will be conducted over the next 2 years to monitor crown condition and tree mortality. Plots will also be tallied for the presence of stem damage (frost cracks, sunscald, wounding), decays, and wood-boring insects. Decays are considered a potentially serious long-term problem to the ice damaged hardwood forest, although a review of the literature (Greifenhagen and Hopkin [In review]) suggests that crown damage is much less of a consideration in this regard than is stem damage, including that from sunscald, as a source of decay. The latter, however, is quite possible in affected coniferous forests where stain and wood borer activity are considered major concerns. At this time it is also the intent to estimate stem decay at permanent plot locations over the next 3 to 5 years.

Given the frequency of ice storms, it is anticipated that forests will recover, although some work suggests declines can be initiated and stand composition altered (De Steven and others 1991, Nicholas and Zedaker 1989). Previous work in Canada has shown improvement in sugar maple forests (Bowers and Hopkin 1997, Lachance and others 1995). Similar improvements have been observed for both maple (Hopkin and Howse 1998) and oak (Hopkin and Howse 1996) species during routine CFS surveys in Ontario. The direct storm damage to the crown and subsequent damage to the stems through sunscald resulting from the open canopies may result in a deterioration of hardwood health in the short term, which may trigger declines.

The existence of this plot system will allow estimates of damage and determination of the likelihood of recovery based on individual species, damage levels, or site conditions. This extensive monitoring of tree health will be integrated with other research projects undertaken in Ontario to provide management guidelines for the existing situation and, given the recurring nature of ice storms, will help to address future needs.

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